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Journal of Experimental Psychology

EDITED BY
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THE REPRODUCTION OF TEMPORAL INTERVALS

BY HERBERT WOODROW

University of Illinois

The bewildering confusion concerning the fundamental facts of the psychology of time has existed for so many years that one might believe that psychologists accepted the situation as inevitable. No insuperable difficulties, however, have been established. It seems reasonable to suppose, therefore, that further experimentation, if sufficiently extensive and precise, should lead to a resolution of the gross inconsistencies and ambiguities which characterize the findings in this field. In furtherance of such an accomplishment several studies have been planned, the present one of which is designed to obtain information regarding the effect of the length of intervals upon the accuracy with which they may be reproduced.

Errors in the reproduction of intervals are customarily termed errors of 'estimation'; and since the nature of alleged errors of estimation has always formed one of the leading topics of the psychology of time-perception, it will further the understanding of the purpose of the present study to scrutinize briefly the fundamental conclusion that appears to have been established. This conclusion, to quote from a recent text-book, is as follows: "there is a human tendency to overestimate short intervals and to underestimate longer ones, the indifference interval lying between seven hundred and eight hundred sigma." [1] What is presumably meant by this statement is not what is stated, but something quite different, namely, that when two intervals of about the same length are

[1] J. F. Dashiell, Fundamentals of objective psychology, 1928, p. 414.

compared with each other, if they are short, the second will commonly seem shorter, whereas if long, the second will seem the longer. But the alleged fact that if both intervals are short the second will seem shorter is just as adequately stated by saying that the first will seem longer. The intervals are 'estimated' only relative to each other and any constant error made is simply an error due to the order of presentation, that is, to the fact that it is impossible to present both intervals under the same conditions, inasmuch as one interval must be the first of a pair and the other the second of a pair. It is just as true, therefore, to say of any short interval that it is underestimated as to say that it is overestimated. It is underestimated if it is the second of a pair of intervals, but overestimated if it is the first of the pair. Irrespective of temporal order, a short interval, so far as may be determined by any of the comparison methods, is neither overestimated nor underestimated.

The only investigations which might possibly justify the general statement that short intervals are overestimated and long ones underestimated are those by the method of reproduction. Several such investigations, each characterized by serious inadequacies, were made in the early days of experimental psychology. The investigation by Vierordt[2] was published eleven years before the date usually given as that of the founding of the first laboratory of experimental psychology. From this laboratory came two other studies on the reproduction of temporal intervals, those by Mehner[3] and by Glass.[4] Mehner's study was conducted mainly by the method of comparison. His data by the method of mean error are so scant as hardly to require consideration. These investigators found that in reproducing short intervals, the subject made them too long, while in reproducing long ones, he made them too short. On account of the shift in the direction of the constant error, they concluded that at some intermediate length of interval no constant error would be made. The length of

[2] K. Vierordt, Der Zeitsinn nach Versuchen, 1868.

[3] M. Mehner, Zur Lehre vom Zeitsinn. *Philos. Stud.*, 2, 1885, p. 594.

[4] R. Glass, Kritisches und Experimentelles über den Zeitsinn. *Philos. Stud.*, 4, 1885, 423–456.

this interval, termed the indifference interval, varied with the investigator and the experimental conditions from 0.75 to 5.0 sec. It is not clear, however, that this indifference interval, that for which errors in reproduction are as apt to be positive as negative, is to be regarded as the same thing as the order-of-presentation indifference interval revealed by the comparison methods. Such an identification has sometimes been made, however, it being alleged that the order-indifference interval of .7 to .8 sec is simply a determination under 'improved' conditions of the same indifference interval involved in the reproduction experiments.[5] To argue the question of the identification of the comparison and reproduction indifferences intervals would not be profitable, since there exists too little certainty at present concerning the nature or even the existence of either of these two varieties of indifference-interval.[6] Clearly, as is indeed widely conceded, the whole matter of errors in comparing and reproducing intervals needs to be further investigated.

The primary aim of the present investigation was to explore with thoroughness and the utmost accuracy the nature of the constant and variable errors made in reproducing intervals of time, and in particular to determine the relationship between these errors and the length of the reproduced interval.

The experimental conditions which need to be mentioned pertain to the following matters: the nature of the intervals and their order of presentation; the subject's task and the manner in which he carried it out; and the apparatus.

The intervals used were empty intervals, bounded by two

[5] C. S. Myers, Text-book of experimental psychology, 2d ed., 1922, p. 299. Mehner on the basis of his own data, published *before* that of Glass, likewise held that the two methods, comparison and reproduction, led to the same indifference interval, namely .7–.8 sec. Mehner's data, however, show 'overestimation' of the longest of his intervals, 3.5 and 5.0 sec., as well as of his shortest, .7 sec.

[6] A third variety of indifference interval, an interval which gives an 'absolute impression' of neither shortness nor longness but has the character of 'moderate' or 'adequate' is usually regarded as quite separate from the indifference intervals discussed above. The interval of indifference as regards absolute impression appears to have a length in the neighborhood of .625 sec. (See the writer's paper on Behavior with Respect to Short Temporal Forms. Part I. Some Hitherto Undescribed Illusions in the Estimation of Short Intervals of Time. This JOURNAL, 1928, XI, p. 190.)

instantaneous impact-sounds produced by an electromagnetic relay used as a sound hammer. These sounds are the clicks resulting from the impact of the arm of the relay, at the end of its outgoing movement, against one of the contact points of the instrument. The intervals were thirteen in number and varied from .2 to 30.0 sec. Each interval was preceded by a warning signal given approximately 2 sec before the initial sound. This warning signal was the sound produced by a buzzer of a frequency of 800 vibrations per sec, the sound varying in duration from .10 to .25 sec. Only one interval was used with a subject on any one day. This interval was presented and reproduced fifty times. Entirely different results might be expected from an experiment in which the various intervals were all employed on one day, particularly if they were used in an irregular order. The work with each subject began with the shortest interval. Each day a longer interval was used until the maximum interval was reached. These series of trials will hereafter be designated the ascending series. When the maximum interval was reached, the order of trials was reversed, beginning this time with a repetition of the day's work with the maximum interval and proceeding regularly by taking up each day the next shorter interval down to the shortest.

The instructions called upon the subjects to reproduce each stimulus-interval as exactly as possible by means of two taps (serving to bound the interval) made upon a Seashore noiseless reaction-key. Indirectly, through certain electrical connections, each tap produced a sound exactly like the sounds used to bound the stimulus-intervals; and thus, while each tap was in itself noiseless, it appeared to the subject to result in a sound which synchronized with the end of the downward movement of his finger. The subjects were warned to inhibit any tendency to count and requested not to make any movements of a rythmical nature with their hands, feet, vocal organs or any other part of the body. They were also requested to make every effort to avoid attention to their breathing. So far as could be judged from the reports of the subjects these instructions were rigorously obeyed. Every three or four

days each subject was asked to write out as full a statement as possible of what he did, that is, of just what was going on in him, as he listened to the intervals and reproduced them. The number of reproductions at one sitting was kept constant at 50 throughout the work. Though the interval never varied throughout the day's sitting, the subjects often reported that the intervals seemed to vary considerably. All subjects were informed, however, that only one interval a day would be used, though they were not informed concerning its length. They were all expressly instructed to reproduce each stimulus-interval independently, that is, no matter how long or how short the interval might at times seem to be, to reproduce it just as it seemed. The subjects, eight in number, were either seniors or graduates, all of whom had taken numerous courses in psychology including a laboratory course. Subject Ww was the writer. In this case, while the subject knew the objective duration of the stimulus-interval, he, like all the other subjects, remained in complete ignorance of the length of his reproductions until the research was completed. A competent assistant took charge of the apparatus and the recording of the data when Ww acted as subject. With this exception, all the experimenting was conducted by the writer.

The apparatus employed in the present experiment is, it is believed, a distinct improvement upon that employed by previous investigators of the reproduction of temporal intervals. All intervals except that of .2 sec were measured by means of a Hipp's chronoscope. The stimulus-intervals were set up with the aid of four different devices. Intervals of .2 sec were controlled by the Klopsteg fall-apparatus, which was likewise used for regulating the Hipp's chronoscope. Intervals of .4 to 1.2 sec were controlled by the Bergstrom chronoscope, large model, and accessories; those of 1.5 sec by means of a Kronecker metronome, and those of 2 to 30 sec by means of a Bowditch-Baltzar contact clock.

The set-up, including a number of relays and storage batteries in addition to the above named instruments, while rather complicated, possesses several definite advantages. One of these is that it enables the experimenter to do away

with the laborious graphic technique, except in the case of the shortest interval, .2 sec. The most important advantage, however, is that it does away with the possibility of appreciable error in the determination of the magnitude of the subject's errors. It should be noted, also, that it permits the subject to tap on the same key, and to execute both taps in exactly the same manner, the first tap beginning the interval (and starting the chronoscope measuring it) and the second tap ending it. It should also be noted that each tap made by the subject produced just the same click as the click used to bound the stimulus-interval, so that the subject reproduced not simply the interval but the entire *gestalt*. In view of these features, the apparatus will be described in detail.

The apparatus, a diagram of which is given below, was constituted primarily of two parts, of which one was the arrangement for giving the stimulus-intervals and the other the set-up for measuring the length of both the stimulus-intervals and the response-intervals. These will be described in the order mentioned.

The stimulus-circuit consisted fundamentally of a pony-relay of 20 ohms resistance (R_4) in circuit with a 6-volt storage battery (A). Breaks produced in this circuit, by releasing the arm of the relay, produced the sounds used to bound the intervals. The noise which would ordinarily be made by the relay's arm upon closing the circuit was cut out by covering the contact nearest the magnets with soft rubber. In consequence, sounds were made in the present instance only at the instants at which the circuit was broken. The two sounds bounding the intervals were made as the result of two breaks in the circuit controlling the relay, the circuit of course being reclosed after the first break. These two breaks were produced, by one or the other of several mechanisms, at B_1 and B_2.

The mechanisms used to produce these breaks, and for closing the circuit after B_1, varied with the length of the interval. For the shortest interval, .2 sec, and for this interval only, the Klopsteg fall-apparatus was used. In this apparatus a steel ball held by a split-core magnet completes the circuit through the two halves of the core. As soon as the circuit which magnetizes the core is broken (by the operation of a key) the ball starts to fall, producing a break at the instant the fall begins. The second break is produced when the falling ball hits a lever placed in its path, this lever being so poised that it is pushed away from a contact at the moment of impact. The Klopsteg apparatus has no arrangement for reclosing the circuit after the first break; and of course a second break in a circuit already broken would be of no avail. This difficulty was overcome by the use of a hand-operated double break-make key, the two halves of which were insulated from each other. A break in one half of this key, resulting in the release of the steel ball and therefore in a break at B_1, was followed almost immediately by a make in the other half, resulting in reclosing the circuit by closing at K_1, the shunt around B_1. This shunt was used only for the purpose just mentioned, with the Klopsteg.

For intervals of .4 sec and over, some variety of pendulum apparatus was used.

For intervals of .4 to 1.2 sec, inclusive, the Bergstrom chronoscope was used. This chronoscope, in the latest model, is fitted with contacts which may be brought into position such that the pendulum will break them in the course of its swing. There is also a contact attached to this chronoscope, though not in the proper position for the present purpose, which will break but close again as soon as the pendulum has swung past it. This contact was brought into position on an arc-shaped support paralleling the trajectory of the pendulum so that the pendulum would strike it very early in its swing. The pendulum thus first produced a break when it hit the first contact, connected with the terminals B_1. This break was automatically closed as soon as the

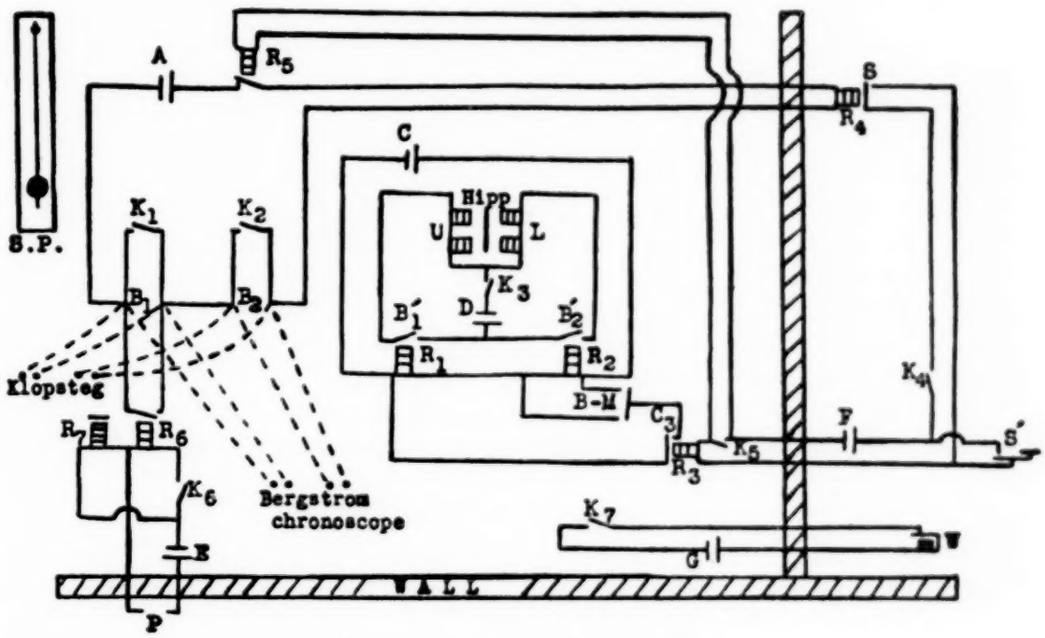

FIG. 1. Diagram of apparatus.

A, C, D, F, storage batteries.

E, G, dry cell batteries.

K_1, one half of a make-break key. The break of the other half, not shown in the diagram, resulted in the release of the steel ball from the electromagnets of the Klopsteg.

K_2, key used to reclose circuit after 2d Bergstrom break. Used only with the Bergstrom apparatus.

B_1, B_2, two breaks, which could be produced by either the Klopsteg or the Bergstrom apparatus.

U, L, upper and low magnets, respectively, of a Hipp's chronoscope.

K_3, K_4, K_5, K_6, K_7, keys.

B-M, break-make key.

R_1, R_2, R_3, R_4, R_5, R_6, relays, 20 ohms resistance.

R_7, relay, 150 ohms resistance.

B_1', B'_2, breaks produced by short-circuiting R_1 or R_2.

C_3, S, S', contacts controlled by R_3, R_4, and subject's key, respectively.

W, high frequency buzzer used as warning signal.

$S.\ P.$, seconds pendulum.

P, contacts produced by either a Kronecker metronome or Bowditch-Baltzar contact clock.

pendulum passed by. The second break was produced when the pendulum hit the second contact, connected with the terminals at B_2. The interval between the two breaks was of course regulated by the distance between the two contacts, the position of the second of which was adjustable. The support carrying these contacts had to be calibrated, by varying the position of the second contact until the already carefully controlled Hipp's chronoscope gave readings of the desired interval.

The longer intervals were controlled through a Kronecker metronome or a Bowditch-Baltzar contact clock, the contacts made by either of which are indicated in the diagram by P. The makes which both of these instruments produce at regular intervals were converted into breaks by having each of the makes at P actuate a relay R_6, so adjusted that whenever the circuit around the magnets of the relay was made, a break was produced in the circuit through the arm. Since both the metronome and the Bowditch-Baltzar clock ran continuously, whereas only two contacts were needed to sound any one stimulus-interval, it is obvious that a key (K_6), was required, by opening or closing which the experimenter could bring into play only such contacts at P as were desired. The high-resistance relay R_7, kept constantly in circuit, enabled the experimenter to keep track of the contacts made by the contact apparatus, something he could not otherwise do since the contacts at P were made in a different room and in fact upon a different floor. It was possible, since all the intervals over 1.5 sec were multiples of .2 sec, to give these intervals by aid of the contact clock set permanently to make contact every 2 sec.

The intervals measured were the intervals between the actual bounding sounds, produced at S. The interval made by the sounds at S was registered by the chronoscope through exactly the same agencies as that produced by the subject's taps at S'. A sound produced at S or a tap upon the subject's key at S' closed the same circuit. Therefore, even should an error of a few sigma have crept into the measurement of the stimulus-interval, the same error would occur in the measurement of the response-interval. Consequently, if the stimulus-interval and its response-interval were the same, they would be measured as the same; and in spite of any error in the obtained length of the stimulus-interval, the constant errors of the subject would be correctly measured.

The set-up for measuring the intervals consisted of the Hipp chronoscope circuit (battery D) and of arrangements for causing either the stimulus-sound contacts (at S) or the subject's key-contacts (at S') to actuate this circuit. The Hipp chronoscope was connected so that it ran from break to break. The circuit through the upper magnets of the chronoscope, U, ran through a relay arm at B_1', and that through the lower magnets, L, through a relay arm at B_2'. These contacts were controlled by the relays R_1 and R_2, which, when shortcircuited, and so rendered impotent, produced breaks at B_1' and B_2' respectively. The chronoscope started as a result of a break at B_1', and stopped upon a break at B_2'. The tension of the springs of relays R_1 and R_2 was great enough to maintain the breaks at B_1' and B_2', even though the circuit through the relay magnets was reclosed. Before each trial, therefore, it was necessary to push the relay arms at B_1' and B_2' back into contact position by hand. They were kept in position by the circuit actuated by battery C. The shortcircuiting of the relays R_1 and R_2 was the result of the first and second taps, respectively, bounding any interval, these taps being those of the sounding-relay R_4, in the case of a stimulus-interval or those of the subject's key, S', in the case of response-intervals. To see how these taps controlled the relays R_1 and R_2, it is necessary to turn attention to the circuit passing from battery F through the arm of the sounding-relay R_4 and the subject's key, S'. This circuit, it

will be observed, governs a relay R_3. Each time the circuit is closed (by either the sound-taps or the subject's key-taps) it causes R_3 to close a short-circuiting shunt around either R_1 or R_2, which one of these depending upon the position of the break-make key (*B-M*). If this key was closed at what in the diagram is its lower end, and open at the upper end, a contact produced at C_3 short-circuited relay R_1 and therefore started the chronoscope. If the key was then shifted to the opposite position, a closing at C_3 short-circuited both R_1 and R_2 and therefore stopped the chronoscope. The key *B-M* was shifted by the experimenter, and it is because the experimenter could not be sure of a reaction-time in manipulating this key of less than about 300 σ that with the interval 200 σ the laborious graphic technique was employed.

The purpose of that branch of circuit *F* which runs to R_4 was to enable the subject at each of his taps to produce a sound identical to that used in sounding the stimulus-intervals, that is, to enable the subject to reproduce the sounds as well as the interval between them. It is obvious from the diagram that whenever the subject by one of his taps closed the circuit (at *S'*) that, K_5 being open, he would actuate the relay R_4 in such a manner as to produce a break at the arm of R_4 in circuit *A*, a break which would produce the usual stimulus-sound at *S*. This all occurred so quickly that to the subject the sound at *S* seemed to occur synchronously with the end of the downward movement of his taps. When stimulus-intervals were being measured, or when the chronoscope was being controlled by means of the Klopsteg fall-apparatus, both K_4 and K_5 were closed, but when stimulus-intervals were simply being sounded for the subject to reproduce, and the response-intervals were being measured, both K_4 and K_5 were open.

To measure each stimulus-interval and its corresponding reproduction was impossible because of the very short time allowed the experimenter to make necessary shifts of keys and contacts in addition to reading the chronoscope. The technique adopted was to take 10 measurements of the stimulus-interval before, and 10 more after, the subject's 50 reproductions. Since the averages of the first and last 10 measurements of the stimulus-interval never differed significantly, it is unlikely that any appreciable error results from assuming that the middle 50 stimulus-intervals had the same length as the average of the 20 which were measured.

As an example of the procedure followed at any sitting, the order of events in the case of the stimulus-interval 1.0 sec may be described. First, the chronoscope was controlled by means of the Klopsteg apparatus, set for 300 σ. The chronoscope was adjusted until it gave within 1 σ of that time for an average of 10 trials, the adjustment being made by aid of the springs of the instrument and by means of resistances (not shown in the diagram) placed in the circuits passing through both the upper and lower magnets. The interval which the chronoscope actually measured while it was being controlled was that between the two sounds made at *S* as the result of the two breaks at B_1 and B_2 due directly to the falling ball. That the time between the two sounds at *S* was exactly equal to that between B_1 and B_2, as it should be, was verified by direct graphic records of the movements of the arm at *S* alongside a 100 dv. tuning fork. It should be stated that R_1 and R_2 and their springs were so adjusted that the time between B_1' and B_2' was also exactly the same as that between B_1 and B_2, though, as has been explained, this was not strictly necessary since any error would be the same in the case of both stimulus and response, and would therefore not affect the obtained constant errors in the subject's reproductions.

After controlling the chronoscope, the Bergstrom was brought into the circuit in place of the Klopsteg (simply by shifting certain keys not represented in the diagram), the contacts of the Bergstrom set to give an interval of 1.0 sec, and 10 measurements

made of the stimulus-interval. In taking the Bergstrom measurements the experimenter had, in order, to close B_1' and B_2' by hand, then K_3, then set the pendulum of the Bergstrom, release the same by hand, shift key *B-M* between the first and second Bergstrom breaks, open K_3 and then read the chronoscope.

The subject then took his place in an adjoining room and measurements were made of his 50 consecutive reproductions, the stimulus-interval being sounded before each reproduction. At each trial the experimenter had first to close the contacts B_1' and B_2' (the springs being so tense that these would not close automatically), close K_3 (always opened between trials), then, watching the wall seconds-pendulum *S. P.*, tap on K_7 2 sec before releasing the Bergstrom pendulum. After the Bergstrom pendulum had completed its swing it was necessary to reclose the second break B_2, by closing K_2, in the circuit which shunts B_2. This K_2 circuit was needed only with the Bergstrom. It will be remembered that the B_1' break of the Bergstrom reclosed automatically. It was necessary also to reclose B_2' before the subject started to reproduce the interval, so that the arm at *S* would be drawn back toward the magnet of R_4 and thus come into position to sound again at the subject's first tap. Between the subject's first and second taps, the experimenter shifted the key *B-M*. Finally, he broke K_3 and took the reading. These operations of the experimenter soon became automatic and very easily carried out. The subject was free to begin his reproduction of the stimulus-interval as soon as he cared to (all the experimenter had to do between the last stimulus and the subject's first tap was to close one key, K_2). The time between trials, that is, between the end of the subject's reproduction and the next warning signal was about 14 sec. No particular attempt was made to keep this interval between trials precisely the same. For the most part it varied from 12 to 18 sec, but was occasionally slightly longer. With an interval of 1.0 sec, only about 15 minutes of the subject's time was required for the reproduction of 50 intervals.

With the 200 σ interval, a Pfeil time-marker was substituted for R_3, and brought to write upon a smoked drum close alongside a similar marker vibrating at the rate of 100 cycles per second. On account of the closeness of the markers to each other it was feasible to use a Zimmerman kymograph with automatically descending drum. It was thus possible to obtain 25 reproductions on one drum. Since two drums were available, both of which were smoked before the sitting began, only one short interruption in the middle of the sitting was needed for changing drums.

Data on the accuracy and constancy of the stimulus-intervals are given in Table I. Each stimulus-interval was measured 20 times at each sitting, in both the ascending and descending series, and therefore a total of 40 times in the case of each subject. Since there were eight subjects in the case of all intervals except the two longest, there were obtained a total of 320 measurements of the length of each stimulus-interval, except the two longest, for which a total of only 200 measurements was obtained. The average of all measurements of each interval is given in Table I in the column headed 'Grand Av.' This grand average is the average of the separate daily means of 20 measurements each. The mean variation in these

daily means is given in the column 'M. V. $_{daily\ means}$'. The degree of accuracy shown by these two columns represents the outcome of constant painstaking control of all contacts, relay spring tensions, amperages, etc., and is certainly far superior to what has been hitherto attained in experiments upon the reproduction of time-intervals. The point to be emphasized, however, is that deviations from the intended intervals shown by the obtained lengths are of no consequence, because the aparatus set-up was such that whatever the length of the stimulus-intervals, the subject's reproductions would give the same readings providing those reproductions were of the same length as the stimulus-intervals. It follows that the obtained constant errors were measured in such a way as to be unaffected by the differences shown in Table I between the intended interval and the average of the measurements obtained of it. These differences, moreover, are so slight that there can be little doubt but that the constant errors for an interval as measured would not differ appreciably from the constant errors of the corresponding intended interval. For example, it is not likely that there would be any appreciable difference as regards the constant errors between an interval of 4000 σ and one of 3991 σ. In the tables showing the constant errors, therefore, the intended intervals are listed in place of the obtained intervals, the former being much easier to keep in mind, and their differences from the latter being negligible.

The average value of the standard deviations of the 20 daily measurements of any stimulus-interval is given in the column headed Av. $\sigma_{dis(20)}$. These daily standard deviations were calculated from measurements of the first and last 10 stimulus-intervals, but may be assumed to correspond very closely with the standard deviation of the middle 50, which were the ones reproduced. The variability in the subject's reproductions was always so much greater than the obtained variability in the stimulus-intervals at the same sitting that it was found not to be worth while, as originally intended, to apply a formula which would give the subject's variability corrected for variability in the measurements of the stimulus-intervals.

A feature of Table I which might at first sight be puzzling is the fact that the variation of means of 20 (M. V. $_{daily\ means}$) is frequently larger than the variability of single measurements (Av. σ_{dis20}). This is due of course to the fact that variation in the means is affected by certain conditions of the apparatus, such as the accuracy of regulation of the chronoscope, which vary from day to day, but are relatively constant at any one sitting.

TABLE I

MEANS AND VARIABILITIES OF THE MEASUREMENTS IN THOUSANDTHS OF A SECOND OF THE STIMULUS-INTERVALS

Intended	Grand Av.	M. V. $_{daily\ means}$	Av. $\sigma_{dis(20)}$
200	199	0.4	2.5
400	404	3.7	3.7
600	602	5.1	5.0
800	805	6.2	7.2
1,000	1,010	6.2	9.8
1,200	1,214	10.0	10.7
1,500	1,514	5.6	8.8
2,000	1,999	12.4	7.8
4,000	3,991	9.8	10.2
6,000	5,993	16.3	9.0
10,000	9,978	27.3	11.7
20,000	20,034	54.6	21.2
30,000	30,062	87.4	19.8

The tables summarizing the obtained data show for each interval and each subject the constant errors and the standard deviations. The constant error, or C.E., is obtained by subtracting the length of the stimulus-interval from the average of the subject's 50 reproductions. If the subject's reproductions were on the average longer than the interval, the C.E. is positive, and if they were shorter, the C.E. is negative. The length of the stimulus-interval used in calculating the C.E.'s was always the average obtained from the 20 measurements of the interval, 10 of which were made immediately before the subject's reproductions and 10 immediately thereafter.

The variability of the subject's reproductions is measured by their standard deviation. In the tables, under each C.E., is given the standard deviation of the distribution of the subject's reproductions of the corresponding interval. If the variation in the stimulus-intervals is regarded as negligible,

then the standard deviation of the subject's reproductions is also the standard deviation of the C.E. In strictness, the C.E. is a difference between two means and its standard deviation is equal to that yielded by the formula for the standard deviation of a difference between two means, i.e., $\sqrt{\sigma_{m(r)}^2 + \sigma_{m(s)}^2}$ in which the mean of the subject's reproductions is $_{m(r)}$ and that of the stimulus intervals, $_{m(s)}$. It was found, however, that the $\sigma_{m(s)}$ was so small as compared with the $\sigma_{m(r)}$ that it could be neglected without significant error. Mean values of $\sigma_{dis(s)}$ for each interval are, however, given in Table I, and these mean values may be used, if desired, after dividing them by $\sqrt{20}$, in calculating for any subject the approximately true standard deviation of the C.E.'s.

The obtained standard-deviation of the distribution of a subject's reproductions is not an exact measure of the variability which actually existed but a compound of the variability of the subject ($\sigma_{r(true)}$) and the variability which was obtained for repeated readings of the length of the supposedly unchanging stimulus-intervals (σ_s), the latter being in turn a compound of the real variability in the sounded intervals and of the variability in the recording apparatus (including any variability on the part of the experimenter in recording the readings of the chronoscope). The real variability of the subject is therefore to be obtained by the formula $\sigma_{r(true)}^2 = \sigma_{r(obt)}^2 - \sigma_s^2$, since $\sigma_{r(obt)}^2 = \sigma_{r(true)}^2 + \sigma_s^2$. It was originally intended by means of this formula to correct all the obtained σ's of the subject's reproductions using as the value of σ_s that calculated from the 20 measurements of the stimulus-interval which were made at each sitting. This correction was found to be so trivial, however, as not to be worth while. For example, the obtained σ_r of the 50 reproductions of subject Ws for the interval .600 sec, ascending series, was 52.8, or 9.2 percent. Correcting this value for the σ_s of the 20 measurements of the stimulus-interval gives a true σ_r of 52.5 or 9.1 percent, a value which does not differ significantly from the uncorrected value. If so desired, however, in all cases such a correction may be made, to a close approximation, by using the average values of Av.$\sigma_{dis(20)}$ given in Table I.

Table II gives the data for the ascending series, that is the first part of the work, in which the intervals were taken in order, one a day, from the shortest interval up to the longest interval. The table shows the C.E. and the obtained σ_{dis} for each subject's 50 reproductions of each interval.

Table III shows the results obtained for the descending series, carried out exactly as the ascending series, except that beginning with the longest interval, at each succeeding day the next shorter interval was used.

Table IV gives the average C.E. for the entire 100 reproductions made by each subject of any one interval. Obviously the C.E.'s of this table are the average of the C.E.'s for the ascending and descending series, the data for which are given in Tables II and III. The σ_{dis}'s of this table are not, however, the average of the σ_{dis}'s of Tables II and III, but the

TABLE II

CONSTANT ERRORS AND STANDARD DEVIATIONS, ASCENDING SERIES

Interval (sigma)	Subject							
	Ws	Fn	Ww	Ke	Kp	Pn	Fl	Ls
200	− 0.4	− 2.6	+ 2.1	+ 30.7	− 2.5	+ 9.6	+ 16.7	+ 10.0
	± *16.4*	± *20.7*	± *24.3*	± *32.3*	± *26.1*	± *22.7*	± *18.3*	± *26.6*
400	+ 1.7	− 26.0	− 4.9	+ 51.2	+ 3.7	+ 44.6	+ 19.6	+ 6.3
	± *40.1*	± *32.9*	± *31.4*	± *40.7*	± *32.4*	± *31.4*	± *23.3*	± *25.2*
600	− 7.7	+ 15.4	+ 1.1	+ 83.4	+ 7.6	+ 51.2	+ 19.0	+ 59.9
	± *25.4*	± *44.4*	± *62.7*	± *29.1*	± *67.7*	± *52.2*	± *40.4*	± *50.6*
800	− 71.4	+ 30.9	+ 5.7	+ 142.0	+ 5.1	+ 47.0	+ 93.4	− 74.1
	± *73.4*	± *51.9*	± *74.1*	± *33.0*	± *70.8*	± *67.2*	± *87.3*	± *89.6*
1,000	− 74.3	− 35.0	− 113.2	+ 47.4	+ 4.2	+ 113.7	+ 47.4	− 12.1
	± *85.8*	± *59.0*	± *129.8*	± *65.3*	± *55.7*	± *74.6*	± *93.9*	± *56.4*
1,200	− 161.8	+ 22.2	+ 21.5	+ 49.3	+ 52.0	+ 259.7	+ 7.6	− 61.8
	± *71.1*	± *91.2*	± *142.8*	± *57.6*	± *73.7*	± *91.7*	± *102.0*	± *89.9*
1,500	− 153.5	+ 95.1	+ 140.1	+ 72.1	+ 63.8	+ 139.0	− 83.4	− 13.8
	± *123.3*	± *112.2*	± *158.9*	± *95.3*	± *130.1*	± *99.8*	± *92.3*	± *147.9*
2,000	− 109.8	+ 153.3	+ 196.0	− 74.5	+ 96.9	+ 387.1	− 31.5	− 117.5
	± *188.0*	± *202.7*	± *225.9*	± *123.8*	± *193.5*	± *123.0*	± *194.1*	± *200.6*
4,000	− 201.5	− 326.5	+ 730.7	− 373.7	+ 93.7	+ 883.6	− 88.5	− 507.0
	± *701.4*	± *434.9*	± *710.4*	± *379.5*	± *651.6*	± *715.5*	± *725.4*	± *601.1*
6,000	+ 504.1	− 270.9	+1087.8	+ 287.1	+ 573.1	+ 345.3	+ 56.3	− 1519.6
	±*1070.7*	±*1036.7*	±*1076.0*	± *863.7*	± *773.9*	± *691.4*	±*1315.4*	± *1058.9*
10,000	+ 791.5	+1014.5	+1056.0	+1157.6	+ 633.2	+1782.5	+ 487.2	− 1363.9
	±*1999.7*	±*2461.4*	±*1286.4*	±*1468.1*	±*1069.5*	±*1832.6*	±*2141.4*	± *1263.6*
20,000	.....	.....	+ 572.7	+4792.1	+1961.5	.....	− 721.7	− 806.2
	.....	.....	±*2899.4*	±*3575.0*	±*2624.9*	.....	±*2937.5*	± *4260.3*
30,000	.....	.....	− 846.9	+4795.5	+2881.2	.....	−1075.7	+ 4403.5
	.....	.....	±*4872.8*	±*4124.1*	±*5720.6*	.....	±*4224.0*	±*10155.9*

σ of the entire 100 reproductions about their own grand average. This σ is always larger than the average of the standard deviations of Tables II and III. The reason for this is that

TABLE III

CONSTANT ERRORS AND STANDARD DEVIATIONS, DESCENDING SERIES

Interval (sigma)	Subject							
	Ws	Fn	Ww	Ke	Kp	Pn	Fl	Ls
200	− 5.6	+ 1.5	+ 5.2	+ 53.6	+ 24.4	+ 18.4	+ 38.1	+ 18.4
	± *15.2*	± *16.4*	± *21.0*	± *20.7*	± *21.8*	± *30.5*	± *25.1*	± *16.2*
400	− 6.4	− 42.9	+ 58.1	+ 111.6	+ 47.2	+ 39.3	+ 16.6	− 40.2
	± *29.9*	± *63.6*	± *30.5*	± *43.5*	± *47.1*	± *33.5*	± *31.4*	± *28.7*
600	− 41.8	− 31.8	− 5.7	+ 188.1	+ 44.0	+ 36.2	+ 7.3	− 1.6
	± *66.0*	± *44.6*	± *39.4*	± *66.6*	± *41.1*	± *49.1*	± *45.2*	± *56.9*
800	+ 4.4	− 37.9	− 25.7	+ 172.5	+ 42.9	+ 80.6	+ 30.9	+ 44.7
	± *89.3*	± *65.9*	± *52.4*	± *43.5*	± *58.2*	± *88.4*	± *71.6*	± *93.3*
1,000	− 48.3	+ 0.8	− 31.0	+ 164.4	+ 39.3	+ 194.2	+ 38.5	+ 55.5
	± *137.4*	± *58.7*	± *69.6*	± *77.6*	± *81.3*	± *125.1*	± *136.4*	± *101.9*
1,200	+ 8.3	− 75.2	+ 41.7	+ 202.0	+ 41.5	+ 131.7	− 148.8	− 28.8
	± *185.4*	± *122.7*	± *158.0*	± *135.9*	± *122.4*	± *150.9*	± *106.8*	± *100.2*
1,500	+ 68.5	− 14.7	+ 129.5	+ 104.7	+ 189.5	+ 37.5	− 115.1	− 118.1
	± *212.9*	± *158.3*	± *172.8*	± *108.5*	± *182.3*	± *131.1*	± *128.0*	± *107.7*
2,000	+ 191.7	+ 23.7	+ 448.2	+ 82.7	+ 44.3	+ 303.4	− 207.2	− 253.5
	± *332.3*	± *226.1*	± *254.1*	± *65.0*	± *207.0*	± *218.9*	± *236.7*	± *253.7*
4,000	+ 11.2	+ 222.4	+ 635.7	+ 851.2	+1159.1	+1046.2	− 617.1	− 745.5
	± *905.9*	± *554.9*	± *499.8*	± *632.1*	± *325.2*	±*1569.3*	± *890.7*	± *624.8*
6,000	− 218.2	+ 356.1	+ 646.3	+1503.1	+ 914.3	+1917.2	+ 25.0	− 985.4
	±*1265.7*	±*1027.5*	± *806.0*	± *879.6*	± *785.6*	±*2875.5*	±*1292.1*	± *919.8*
10,000	+ 952.6	+2123.8	+1099.2	+2274.9	+1057.2	+2575.4	+ 211.2	−1201.4
	±*2394.2*	±*1784.1*	±*1689.9*	±*1807.8*	±*2223.8*	±*2427.0*	±*2281.5*	±*1650.3*
20,000	.....	.....	−2386.6	+2625.6	+1138.6	.....	−1531.5	− 400.1
	.....	.....	±*2769.9*	±*2463.9*	±*3981.5*	.....	±*3377.9*	±*4742.1*
30,000	.....	.....	−2003.2	+2747.9	+5044.6	.....	−4317.9	+2875.4
	.....	.....	±*3497.0*	±*5024.6*	±*6290.7*	.....	±*5203.7*	±*6180.2*

the mean C.E. of a subject in the ascending series always differed, and often considerably, from his C.E. in the descending series. The explanation of this fact will be discussed later. That it should produce an increase in the σ's shown in Table IV over those shown in Tables II and III is obvious from inspection of the formula for the σ of the grand average (mean of 100 trials), which is $\sigma_{100}^2 = \frac{1}{2}(\sigma_{ascending}^2 + \sigma_{descending}^2 + \frac{1}{2} D^2$ in which D is the difference between the two mean C.E.'s (or what amounts to the same thing, the difference between the means of the subject's 50 reproductions, ascending series, and his 50 reproductions, descending series).

TABLE IV

CONSTANT ERRORS AND STANDARD DEVIATIONS, ASCENDING AND DESCENDING SERIES AMALGAMATED

Interval (sigma)	Subject							
	Ws	Fn	Ww	Ke	Kp	Pn	Fl	Ls
200	− 3.0	− 0.6	+ 3.7	+ 42.2	+ 11.0	+ 14.0	+ 27.4	+ 14.2
	± *16.0*	± *18.8*	± *22.8*	± *29.5*	± *27.6*	± *27.2*	± *24.4*	± *22.4*
400	− 2.4	− 34.5	+ 26.6	+ 81.4	+ 25.5	+ 42.0	+ 18.1	− 17.0
	± *35.6*	± *51.3*	± *44.2*	± *51.8*	± *45.9*	± *32.6*	± *27.7*	± *35.7*
600	− 24.8	− 8.2	− 2.3	+ 135.8	+ 25.8	+ 43.7	+ 13.2	+ 29.2
	± *52.8*	± *50.4*	± *52.5*	± *73.3*	± *58.9*	± *51.2*	± *43.3*	± *62.0*
800	− 33.5	− 3.5	− 10.0	+ 150.6	+ 24.0	+ 43.8	+ 62.2	− 14.7
	± *90.1*	± *68.6*	± *66.1*	± *49.2*	± *67.5*	± *80.3*	± *85.7*	± *109.1*
1,000	− 61.3	− 17.1	− 72.1	+ 105.9	+ 21.8	+ 154.0	+ 43.0	+ 21.6
	± *115.3*	± *61.5*	± *112.0*	± *92.5*	± *71.8*	± *110.5*	± *116.9*	± *89.1*
1,200	− 76.8	− 26.5	+ 31.6	+ 125.7	+ 46.8	+ 195.7	− 70.6	− 45.3
	± *163.8*	± *118.5*	± *151.0*	± *129.4*	± *100.9*	± *140.4*	± *130.5*	± *96.5*
1,500	− 42.5	+ 40.2	+ 134.8	+ 88.4	+ 126.7	+ 88.3	− 100.8	− 66.0
	± *206.3*	± *147.5*	± *166.3*	± *103.7*	± *170.2*	± *127.0*	± *112.7*	± *139.6*
2,000	+ 40.9	+ 88.5	+ 322.1	+ 4.1	+ 70.6	+ 345.3	− 119.4	− 185.5
	± *309.1*	± *224.4*	± *271.4*	± *126.4*	± *252.2*	± *182.5*	± *233.7*	± *238.9*
4,000	− 95.2	− 52.1	+ 683.2	+ 238.8	+ 626.4	+ 964.9	− 352.8	− 626.3
	± *817.0*	± *569.1*	± *615.9*	± *804.0*	± *741.3*	± *1222.2*	± *854.1*	± *624.5*
6,000	+ 143.0	+ 42.6	+ 867.1	+ 895.1	+ 743.7	+ 1131.3	+ 40.7	− 1252.5
	± *1226.8*	± *1079.0*	± *976.0*	± *1063.1*	± *798.5*	± *2234.3*	± *1303.6*	± *1027.2*
10,000	+ 872.1	+ 1569.2	+ 1077.6	+ 1716.3	+ 845.2	+ 2179.0	+ 319.2	− 1282.7
	± *2207.5*	± *2219.7*	± *1501.8*	± *1739.1*	± *1757.9*	± *2186.7*	± *2216.9*	± *1472.0*
20,000	.....	.....	− 906.9	+ 3708.9	+ 1550.2	.....	− 1126.6	− 603.2
	.....	.....	± *3198.3*	± *3255.6*	± *3397.4*	.....	± *3344.5*	± *4512.0*
30,000	.....	.....	− 1425.1	+ 3771.9	+ 3962.9	.....	− 2696.8	+ 3639.5
	.....	.....	± *4280.4*	± *4709.3*	± *6109.3*	.....	± *5008.9*	± *8441.1*

The C.E.'s for different intervals may be more readily compared after they have been changed from absolute to relative, or percentage C.E.'s. Table V gives the relative C.E.'s for the ascending and descending series and the average of these, in the case of each interval and each subject. The study of this table brings out the most important conclusions of the present investigation. It will be observed at once that there is no even remotely uniform tendency for the C.E.'s to change from positive to negative at .8 sec, 1.25 sec, or any other interval. Incidentally, it should be pointed out that mere fluctuation in the sign of the C.E.'s does not necessarily establish an indifference interval any more than does the fluctuation in one's interpretation of an ambiguous perspective demonstrate the existence of a neutral interpretation. In the case of none

TABLE V

CONSTANT ERRORS AS PERCENTAGES OF THE CORRESPONDING STIMULUS-INTERVALS

		Ws	Fn	Ww	Ke	Kp	Pn	Fl	Ls
200	Ascending	− 0.2	− 1.3	+ 1.1	+15.4	− 1.3	+ 4.8	+ 8.4	+ 5.0
	Descending	− 2.8	+ 0.8	+ 2.6	+26.8	+12.2	+ 9.2	+19.1	+ 9.2
	Av	**− 1.5**	**− 0.3**	**+ 1.9**	**+21.1**	**+ 5.5**	**+ 7.0**	**+13.8**	**+ 7.1**
400	Ascending	+ 0.4	− 6.5	− 1.2	+12.8	+ 0.9	+11.2	+ 4.9	+ 1.6
	Descending	− 1.6	−10.7	+14.6	+27.9	+12.3	+ 9.8	+ 4.2	−10.1
	Av	**− 0.8**	**− 8.6**	**+ 6.7**	**+20.4**	**+ 6.6**	**+10.5**	**+ 4.6**	**− 4.3**
600	Ascending	− 1.3	+ 2.6	+ 0.2	+13.9	+ 1.3	+ 8.5	+ 3.2	+10.0
	Descending	− 6.9	− 5.3	− 0.9	+31.4	+ 7.3	+ 6.0	+ 1.2	− 0.8
	Av	**− 4.1**	**− 1.4**	**− 0.4**	**+22.7**	**+ 4.3**	**+ 7.3**	**+ 2.2**	**+ 4.1**
800	Ascending	− 8.9	+ 3.9	+ 0.7	+17.8	+ 0.6	+ 5.9	+11.7	− 9.3
	Descending	+ 0.6	− 4.7	− 3.2	+21.6	+ 5.4	+10.1	+ 3.9	+ 5.6
	Av	**− 4.2**	**− 0.4**	**− 1.3**	**+19.7**	**+ 3.0**	**+ 8.0**	**+ 7.8**	**− 1.9**
1,000	Ascending	− 7.4	− 3.5	−11.3	+ 4.7	+ 0.4	+11.4	+ 4.7	− 1.2
	Descending	− 4.8	+ 0.1	− 3.1	+16.4	+ 3.9	+19.4	+ 3.9	+ 5.6
	Av	**− 6.2**	**− 1.7**	**− 7.2**	**+10.6**	**+ 2.2**	**+15.4**	**+ 4.3**	**+ 2.2**
1,200	Ascending	−13.5	+ 1.9	+ 1.8	+ 4.1	+ 4.3	+21.7	+ 0.6	− 5.2
	Descending	+ 0.7	− 6.3	+ 3.5	+16.8	+ 3.5	+11.0	−12.4	− 2.4
	Av	**− 6.4**	**− 2.2**	**+ 2.7**	**+10.5**	**+ 3.9**	**+16.4**	**− 5.9**	**− 3.8**
1,500	Ascending	−10.2	+ 6.3	+ 9.3	+ 4.8	+ 4.4	+ 9.3	− 5.6	− 0.9
	Descending	+ 4.6	− 1.0	+ 8.6	+ 7.0	+12.6	+ 2.5	− 7.7	− 7.9
	Av	**− 2.8**	**+ 2.7**	**+ 9.0**	**+ 5.9**	**+ 8.5**	**+ 5.9**	**− 6.7**	**− 4.4**
2,000	Ascending	− 5.5	+ 7.7	+ 9.8	− 3.7	+ 4.8	+19.4	− 1.6	− 5.9
	Descending	+ 9.6	+ 1.2	+22.4	+ 4.1	+ 2.2	+15.2	−10.4	−12.7
	Av	**+ 2.1**	**+ 4.5**	**+16.1**	**+ 0.2**	**+ 3.0**	**+17.3**	**− 6.0**	**− 9.3**
4,000	Ascending	− 5.0	− 8.2	+18.3	− 9.3	+ 2.3	+22.1	− 2.2	−12.7
	Descending	+ 0.3	+ 5.5	+15.9	+21.3	+29.0	+26.2	−15.4	−18.6
	Av	**− 2.4**	**− 1.4**	**+17.1**	**+ 6.0**	**+15.7**	**+24.2**	**− 8.8**	**−15.7**
6,000	Ascending	+ 8.4	− 4.5	+18.1	+ 4.8	+ 9.6	+ 5.8	+ 0.9	−25.3
	Descending	− 3.6	+ 5.9	+10.8	+25.1	+15.2	+32.0	+ 0.4	−16.4
	Av	**+ 2.4**	**+ 0.7**	**+14.5**	**+15.0**	**+12.4**	**+18.9**	**+ 0.7**	**−20.9**
10,000	Ascending	+ 7.9	+10.1	+10.6	+11.6	+ 6.3	+17.8	+ 4.9	−13.6
	Descending	+ 9.5	+21.2	+11.0	+22.7	+10.6	+25.8	+ 2.1	−12.0
	Av	**+ 8.7**	**+15.7**	**+10.8**	**+17.2**	**+ 8.5**	**+21.8**	**+ 3.5**	**−12.8**
20,000	Ascending	.....	.....	+ 2.9	+24.0	+ 9.9	.....	− 3.6	− 4.0
	Descending	.....	.....	−11.9	+13.1	+ 5.7	.....	− 7.7	− 2.0
	Av	.....	.....	**− 4.5**	**+18.6**	**+ 7.8**	.....	**− 5.7**	**− 3.0**
30,000	Ascending	.....	.....	− 2.8	+16.0	+ 9.6	.....	− 3.6	+14.7
	Descending	.....	.....	−11.7	+16.7	+21.3	.....	+17.3	+20.6
	Av	.....	.....	**− 7.3**	**+16.4**	**+15.5**	.....	**+ 6.9**	**+17.7**

of the subjects in the present investigation was there found any such proof of any indifference interval as would be afforded by a regular reduction in the magnitude of C.E.'s of one sign up to a certain point and a regular and progressive increase in C.E.'s with the opposite sign beyond this point.

Individual differences in the C.E. are so great that to average these C.E.'s is not a very enlightening procedure. A better idea of the facts may be obtained by studying the subjects individually. It will then be observed that not one of the subjects did what would be expected according to the traditional statement that short intervals are overestimated and long ones underestimated. For only one subject are the data even remotely in accord with this statement. This subject is Fl, whose C.E.'s shift (according to the averages of the ascending and descending series) from positive to negative between 1.0 and 1.2 sec, only, however, to shift back from negative to positive between 4.0 and 6.0 sec and once more to shift from positive to negative between 10.0 and 20.0 sec. On the other hand, two subjects show very definitely the diametrically opposed tendency, their C.E.'s being (according to the averaged data) negative for all of the shorter intervals and then, after a range of intervals in which the sign of the C.E.'s fluctuates, changing to positive for the two longest intervals (with these subjects 6 and 10 sec). The remaining five subjects, the majority, showed no definite shift in the sign of their C.E.'s. Three of them, Ke, Kp, and Pn, showed positive C.E.'s throughout the entire range of intervals while the remaining two, Ww and Ls, oscillated irregularly from positive to negative C.E.'s, with a preponderance of positive C.E.'s for the longer intervals in the case of Ww and of negative C.E.'s for the longer intervals in the case of Pn.

The above facts establish beyond question that whether the reproductions of an interval will be longer or shorter than that interval depends upon the subject. Not only do the C.E.'s vary from subject to subject, but they often vary enormously for a given interval with the same subject at different sittings. The C.E.'s given in Table II differ in sign from the corresponding C.E.'s of Table III (C.E.'s for the same interval and sub-

ject) in 28.6 percent of the cases. More in particular, then, the C.E.'s depend upon the attitude or mode of reproducing the intervals which the subject may happen to adopt. Some modes of reproducing lead to positive C.E.'s and others to negative C.E.'s; but either of these modes may be adopted equally well in the case of any of the intervals used in the present study, whether long, short or medium.

In addition to the C.E.'s, the nature of which has just been summarized, an interesting measure yielded by the method of mean error is that of the variability of the reproductions. The measure of variability which has been used is the standard deviation. Tables II, III and IV give the σ_{dis} of each subject for each interval. In order to facilitate the determination of any general tendencies, the results for all subjects have been amalgamated. Three somewhat different methods of making this amalgamation have been used and the results obtained by each of these methods are given in Table VI. One method is simply to take for each interval the average of the sixteen σ's given in Tables II and III. This method ignores the differences in the C.E.'s of different subjects and also those in a given subject in the ascending and descending series. The value which it yields is given in Table VI in the columns headed Av. σ. The second method is similar to the first except that in place of taking the arithmetical average of the σ's, the square root of the average of their squares is used. The obtained value is called σ_0 in Table VI. The third method is to calculate for each interval the actual standard deviation of all the reproductions by all the subjects, taken as one group of reproductions. This standard deviation will of course be larger than the others because it includes both the variation in the means of the different subjects and that of a given subject in the two series, ascending and descending. It is calculated by the formula $\sigma_t^2 = (\sum\sigma^2 + \sum d^2)/n$ in which σ represents the individual σ's given in Tables II and III, d the distance of the respective mean C.E.'s from the grand average of all the C.E.'s for the interval in question, and n the number of means (10 for the two longest intervals, 16 for all others). Table VI gives each of these three varieties of standard deviation both

as an absolute value and as a precentage, not of the length of the stimulus, but of the mean length of the amalgamated reproductions.

The data of Table VI may be readily summarized by first

TABLE VI

STANDARD DEVIATIONS, DATA FOR ALL SUBJECTS AMALGAMATED

Interval (sigma)	Av. σ		σ_0		σ	
	Absolute	Percent	Absolute	Percent	Absolute	Percent
Eight Subjects						
200	22.1	10.3	22.7	10.6	27.8	13.0
400	35.4	8.5	36.6	8.0	53.4	12.8
600	48.8	7.8	50.4	8.0	72.8	11.6
800	69.4	8.4	71.4	8.6	97.7	11.8
1,000	88.0	8.6	92.6	9.0	122.2	11.9
1,200	112.6	9.2	117.6	9.6	159.4	13.0
1,500	135.1	8.8	139.1	9.1	172.6	11.3
2,000	208.5	10.1	218.0	10.5	293.7	14.2
4,000	682.7	16.4	736.7	17.6	956.3	22.9
6,000	1108.7	17.5	1214.7	19.2	1470.4	23.2
10,000	1861.3	17.1	1908.9	17.5	2175.1	19.9
Five Subjects						
4,000	603.1	14.7	624.5	15.2	903.5	22.0
6,000	977.1	15.6	996.8	15.9	1330.5	21.3
10,000	1688.2	16.0	1735.5	16.5	2061.7	19.6
20,000	3363.2	16.4	3440.0	16.7	4004.4	19.5
30,000	5529.4	17.6	5802.5	18.4	6573.7	20.9

describing the general trend as seen in the average values given in the column headed 'Av. σ', and then pointing out to what extent the reliability of the general trend is vitiated on account of the divergencies of the individual trends or of the trends shown in the other two columns of the table, headed σ_0 and σ_t. On the average, as the length of the stimulus-interval increases, the relative standard deviation at first regularly decreases from 10.3 percent at 200 σ to a minimum of 7.8 percent at 600 σ, and then regularly increases, with one exception (the variability at 1200 σ being slightly greater than at 1500 σ), up to the interval 4000 σ beyond which point the relative variability changes but slightly. The general trend shows, then, the following characteristics:

(1) The smallest variability occurs at .6 sec. That no great dependence may be placed upon this feature is indicated by the fact that 5 of the 8 subjects showed smaller variability at some other interval than .6 sec. Moreover, the column σ_o shows no significant difference between the variability at .6 sec and that at any of several other intervals.

(2) A striking increase in the average relative variability occurs between 1.5 and 4.0 sec, the variability being nearly twice as great at the latter of these two intervals as at the first. Something similar holds for all individuals. All individuals but one, subject Kp, show significantly greater variability for intervals of 4 sec and over than for intervals of 1.5 – 0.6 sec; and in the case of subject Kp, the variability is significantly greater for 10 sec and beyond than for any of the shorter intervals.

(3) From 4 sec on, variation in the average relative variability is very slight. Since only 5 subjects were given intervals of 20 and 30 sec, it is necessary to consider separately the results with 8 subjects for intervals 4–10 sec and with 5 subjects for intervals 4–30 sec. If the true variability for intervals of 4 sec and beyond is regarded as constant and taken to be the average of the variabilities for these intervals, then it may be said that with 8 subjects no very significant deviation from this assumed constant variability is shown by the average variability for any of the three intervals, 4, 6, or 10 sec. With 5 subjects, however, the average variability for 4 sec is reliably less ($4 \times \sigma_o$) and for 30 sec, reliably greater (also $4 \times \sigma_o$) than such an assumed constant variability. In short, the data for 5 subjects show that variability keeps on regularly increasing, though very slightly, from 4 to 30 sec inclusive. On the other hand, the column showing the variability in the reproductions of all subjects regarded as a single group (σ_t), shows somewhat greater variability at 4 and 6 sec than at 30 sec. On the whole, the data are rather indecisive as to whether a Weber's law relationship holds for intervals beyond 4 sec or not. They do establish, however, that there is on the average very little change in the relative variability beyond 4 sec. An examination of the variabilities of the individual subjects reveals that

in the case of only one subject (Kp) is there any significant increase in variability beyond 6 sec.

The marked increase in variability between 1.5 and 4–6 sec shown in Table VI suggests that it is within this region that there occurs the only really marked change in the quality of the psychosomatic functions involved in the experiment. Such a suggestion is confirmed by a study of the comments of the subjects all of whom beginning with some interval varying from 2–6 sec state that the task becomes much more difficult so that they feel more or less 'lost'. For example, subject Ls, after reproducing the 6 sec interval, writes: "With this interval I have no feeling of certainty that the reproduction is even approximately accurate. I give the final tap ending the reproducing interval on a sort of 'hunch' the origin of which I am unable to trace"; and subject Fl writes: "With the shorter intervals I think I always knew if I made any considerable error in the reproduction but with this interval (4 sec) it was simply a lot of guess work and I had no idea in which direction the errors were made."

Another point brought out by the introspective reports was that the experience of duration becomes definite only with the longer time-intervals, that is, those beyond 1.5 sec. "In the long intervals there is a feeling of duration—of something going on, perhaps in a line—while there is no such experience for the short intervals." The subjects seemed all to be of the opinion that, if there is any experience which deserves to be called the perception of time, that such experience begins to become definite only at 1.5 to 6 sec, and continues as much the same quality of experience throughout all the longer intervals. It should be noted, further, that it is very doubtful if any of the introspections give any support to the notion that the estimation of long intervals is an estimation of a rhythmical nature, a sort of chain-like affair in which consciously or unconciously one counts the links. It is true that the reports mentioned noticing the breathing (and hastening to attend to something else) and to series of thoughts, but in no case did the subjects have the impression that anything resembling an unconscious counting of these was involved. On the other hand, they were

unable to detect introspectively any process which would explain just how they did manage to reproduce the intervals. It is out of the question to give in full or even to summarize the scores of reports obtained. It must suffice to cite one sample of those rather numerous reports which frankly recognized the impossibility of detecting the nature of the time-reproduction process by means of introspection. Subject Fl, after reproductions of the 30 sec interval, reports as follows: "When the tap beginning the stimulus-interval is sounded I almost go to sleep—only a faint pressure is felt somewhere in my head, and I have a dim idea how the click sounded. This condition lasts until the tap ending the stimulus-interval. Then I awake myself from this strange daze, open my eyes for a second, often startle just a little, tap the reaction key then go back into the daze. This second daze is as the first except that it is usually a little more relaxed, not so much pressure in my head. Sometime during the second daze, I begin to feel strained, and may even open my eyes. Something woke me! So I make my second tap on the reaction key." This report is not representative of those of other subjects, except in the fact that like them it offers no explanation of the time-reproducing process.

One further set of observations made in the course of the experiment should be mentioned. These observations pertained to the time that the subject allowed to elapse between the end of the stimulus-interval and his own first tap. The subject was allowed to delay his reproduction by whatever interval he pleased, except that he was asked to delay at least a half-second (in order to give the experimenter time to close a key forming part of the aparatus). The observations of the subject's delays were not carried out systematically and were made simply by means of a stop-watch. It may be said definitely, however, that no subject ever delayed his reproduction, on the average throughout a sitting, by more than 3.0 sec. In fact with all subjects except one, the average delays were always between 1.8 and 2.7 sec, and without any very striking variation in the length of the delay with the length of the stimulus-interval. In the case of one subject, however, Ls, the

delays showed a fairly regular progression from 1.25 sec on the average with the .4 sec interval (with the .2 interval delays were not measured) up to 2.6 sec with the 30 sec interval. The mean variation in any delay varied from 10 to 25 percent of its average duration. So far as could be determined, data concerning the delay of the subjects in initiating their reproductions have no significant bearing upon the accuracy of the subjects' performances nor upon the nature of the individual differences.

The reports of the subjects were particularly disappointing in not affording an explanation of the marked individual differences in the constant errors. It was evident that wide variation in these reports might be unaccompanied by any obvious difference in the subjects' performances. Even when supplemented, at the end of the investigation, by prolonged discussion and further trials taken in order to enable the subject to verify or to amplify his statements, the reports served only to suggest very hypothetical explanations of the individual differences in the C.E.'s These suggested hypotheses were to the effect that the C.E.'s were due primarily to the difference between the task of listening to an interval and that of reproducing it, and that individual differences in the C.E.'s were due to differences in manner in carrying out one or the other of these two tasks.

Several hypotheses were tried out, though not with any great thoroughness, by instructing a subject in first one attitude and then in a different one, and then determining the effect of the difference in instructions upon the C.E.'s. The results were discouragingly negative. Numerous variations in instructions appeared to have no reliable effect upon a given subject's C.E.'s.

Finally, however, a factor was discovered which did cause an astonishing effect upon the C.E.'s. When the subjects were instructed to reproduce in an automatic manner, to pay no attention to their finger movements but to attend primarily to the sounds, and to think of the interval as 'out there' somewhere, i.e., between the sounds, the result was that the reproductions were relatively short. When, however, the subjects were instructed to reproduce by thinking of their movements,

attending to their fingers, and concentrating on just when the terminal tap should be given, the reproduction was in all cases much too long.[7]

The conclusions reached in the present investigation concerning the nature of the C.E.'s are decidedly at variance with those of Vierordt and Glass. On account of the marked individual differences discovered in the present study, however, it is not difficult to understand how, with only one or two subjects, results differing from the present might have been obtained. Glass was himself his only subject, and Vierordt likewise, in his work on the reproduction of intervals bounded by sounds, used only himself, except in one experiment in which his own results were supplemented by much less extensive data concerning one additional subject. Thus, work of both of these investigators taken together gives data from a total of only three subjects, of whom two were the experimenters themselves. Mehner's rather fragmentary results, obtained with only himself as subject, agree better with those of the present study inasmuch as they suggest, contrary to his own interpretation of them, that the direction of the constant error is not a function of the length of the interval. Mehner underestimated intervals which both Vierordt and Glass overestimated, those from .8 to 1.5 sec inclusive, and he overestimated intervals which they underestimated, intervals of 3.5 and 5.0 sec. Mehner, it is true agrees with Vierordt and Glass in overestimating intervals of less than .8 sec, but he used only one such interval, namely .7 sec. This latter interval is thus the only interval below 3.5 sec which he by actual trial found to be overestimated.

In the case of the variable errors, the task of reconciliation is not so easy—partly because the results of Vierordt, Mehner and Glass are themselves decidedly at variance. Glass's finding that the variable error closely follows Weber's law between

[7] This attitude should not be identified with the 'motor' attitude in the reaction-time experiment. Motor reaction times are shorter than others, whereas the attitude here described causes the reproductions to be longer. Moreover, it may well be questioned whether there is any difference in motor and sensory reaction times once the suggestion is eliminated that the subject in one case react as quickly as possible and in the other case as quickly as he may please.

the limits of 0.7 and 15.4 sec is reliably contradicted by the results of every one of the eight subjects used in the present study, each of whom showed a great increase in the variable error with lengthening of the interval.[8] On the other hand, the results obtained with these eight subjects do not violently disagree with those obtained by Vierordt, and harmonize well with the latter's statement that the minimum variation occurs with the interval 0.6 sec.

Summary

Empty temporal intervals bounded by two clicks, the intervals varying from .2 to 30.0 sec, were presented to each of eight subjects, who reproduced each interval by taps upon a key. The duration of the stimulus-intervals was accurately controlled and these durations as well as those of the subject's reproductions measured by means of a Hipp chronoscope. From the average of the subject's reproductions was subtracted the duration of the stimulus-interval, to obtain, for each duration of the latter, the subject's constant error (C.E.). As a measure of the variability in the subject's reproductions, the standard deviation was calculated. A study of the constant errors revealed the following facts:

1. There was no universal tendency for long intervals to be underestimated (to yield negative C.E.'s) or for short ones to be overestimated (to yield positive C.E.'s). Each of the intervals was underestimated by some of the subjects and overestimated by the others.

2. Some subjects underestimated short intervals and overestimated long ones. Some did the reverse. Some varied from overestimation to underestimation irregularly with change in the length of the interval. Some subjects overestimated all the intervals.

3. The subject sometimes overestimated an interval on

[8] The writer believes that Glass's data, obtained only with himself as subject, with apparatus so crude that he felt it necessary to make a correction of 50 sigma throughout, this correction being simply a guess as to the average length of an error which, by its very nature, must actually have been quite variable, do not measure up to present standards of acceptable scientific evidence. The evidence cited by Glass in support of a periodic law in the C. E.'s breaks down upon statistical analysis and should not be taken seriously.

one day and underestimated it on a different day. This change in the sign of the C.E.'s of the same subject was noted in 28.6 percent of the cases.

4. At the end of the investigation, additional data were obtained showing that a difference in the attitude of a subject could bring about a reversal in the sign of his constant error. The hypothesis is suggested that the constant errors and individual differences therein are mainly the result of differences in attitude which the individuals take in listening to, and in reproducing, the intervals.

The standard deviations showed the following general tendencies:

1. The relative variability (σ_{dis}/mean), far from remaining constant over the entire range of intervals, was much smaller for the shorter intervals than the longer ones.

2. For intervals of 6 sec and beyond there is on the average very little change in the relative standard deviation.

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CERTAIN FACTORS DETERMINING THE ACCURACY OF A RESPONSE TO THE DIRECTION OF A VISUAL OBJECT[1]

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In the monograph *The Development of a New Spatial Co-ordination* Miss Wooster[2] reports experiments in which subjects attempted to localize an object in a visual field which had been distorted by means of prism glasses. The distortion was approximately 21 degrees to the right, but the subjects were informed neither of its extent nor direction. In an initial standard series the subjects localized the object at points consistently to the right of its actual position in front of the body. As trials progressed, and although no information concerning the error was given, the distance between the object and the point at which it was localized was gradually reduced. After ten days or 200 trials this distance had been decreased 40.5 percent, and the reduction continued until only 41 percent of the initial deviation remained. Then readjustment stopped. With no apparent sensory cues of the position of the object except those of distorted vision, and with no indication of the error, its extent or direction, the subjects readjusted by reducing the error nearly 60 percent in the series of trials.

Knowledge of the extent and direction of the distortion, and of bodily orientation in reference to the visual world through contact may have been responsible for the readjustment. A control experiment was conducted in which the possibility of obtaining such knowledge was presumably excluded.[3] Readjustment in this series was as marked as it had been in the original experiment.

[1] This study was carried on in the Psychological laboratory at the University of Chicago. The writer wishes to express appreciation to Professor Carr for his aid in developing the problem, for his direction in the course of experimentation, and for his suggestions and criticisms during preparation of the manuscript.

[2] WOOSTER, M., *Psychol. Monog.*, Vol. 32, No. 4.

[3] WOOSTER, p. 30.

The hypothesis finally accepted to account for the readjustment is stated by Miss Wooster. "It is the habitual tendency to react to the front as determined by head position rather than eye position which conditions the tendency to readjust to the left." [4]

When a subject fixates an object under normal conditions of vision preparatory to making a localizing arm movement toward it, he habitually tends to adjust so that the object is located approximately in the median plane of the body, or directly in front of him. There are four possible factors which enable him to determine when the object is directly in front of him. 1. There is a visually perceived relation of the object to the trunk of the body. The subject sees the object, sees his body, and apprehends the spatial relation between them. This factor was eliminated in Miss Wooster's study by the conditions of the experiment. 2. Since the median plane of the head roughly coincides with the median plane of the body, this somesthetically perceived relation may be utilized in effecting the localizing arm response. 3. Similarly, the somesthetically felt relation of eyes to head and to body may serve as an aid. 4. The subjects may come to rely upon the central position of the object in the visual field in judging the location of the object in reference to the median plane of the body.

In making their localizing reactions, Miss Wooster's subjects adjusted themselves to the apparent or illusory location of the object, that is, they turned the body until the object appeared to be located directly in front of them. Under these conditions the illusory object was located in the center of the restricted field of vision and in the median plane of the eyes and of the trunk of the body. The three factors of eye position, body position, and position of the object in the visual field are supposedly responsible, though indirectly, for the erroneous arm movement in pointing at the fixated object. Further, the influence of the prisms made it necessary for the subjects to turn the head to the left in reference to the rest of the body in order to fixate the object and still see it in the center of the field of vision. In other words, the median plane of

[4] WOOSTER, p. 43.

the head did not coincide with the median plane of the eyes or torso, but was turned in the direction of the real location of the object. Miss Wooster suggested that it was this deviation of the head position that deflected the arm reaction in the direction of the true location of the object and thus minimized the degree of error.

Our experiment developed from this conception. This experiment was designed to test the efficacy of the two factors—head position and the position of the object in the visual field—in making a localizing arm reaction to a fixated object. Our study was unlike Miss Wooster's in that no prisms were used and the subjects adjusted themselves to the real position of the object. The means of controlling the head position and the position of the object in the field of vision, and of holding other factors constant will be given in connection with a description of the apparatus and the method.

Apparatus

The apparatus upon which the localizations were made consisted of a curved metal backplate upon which the object to be localized was placed. From that backplate and at right angles to it two boards extended in shelf-like arrangement, one at the lower edge of the plate, the other six inches above the first. Two boards at the ends held the shelves in position and completed the box open on the near side and closed on the far side by the curved back. This apparatus is illustrated in Fig. I.A. *Bp* is the backplate upon which is suspended the object (*O*), a metal strip of a color different from that of the back. This box was set upon legs of adjustable length.

Figure I. B is a diagram of the apparatus as viewed from above and shows the position of the shield or screen (*Scr*). When in use this screen rested about the shoulders of the subject (*S*) and hid his body and arms from his own view.

The upper board of the apparatus was separated from the backplate by a space five-eighths of an inch wide. Half of that space was taken up by the scale upon which the readings were taken. The other half constituted the opening through which the experimenter noted the position of the subject's

responding finger relative to the position of the object. A section of that space showing the scale and the object in place is presented in Fig. I. C

The eye piece worn by the subject during each sitting consisted of two short tubes—one for each eye—which were set

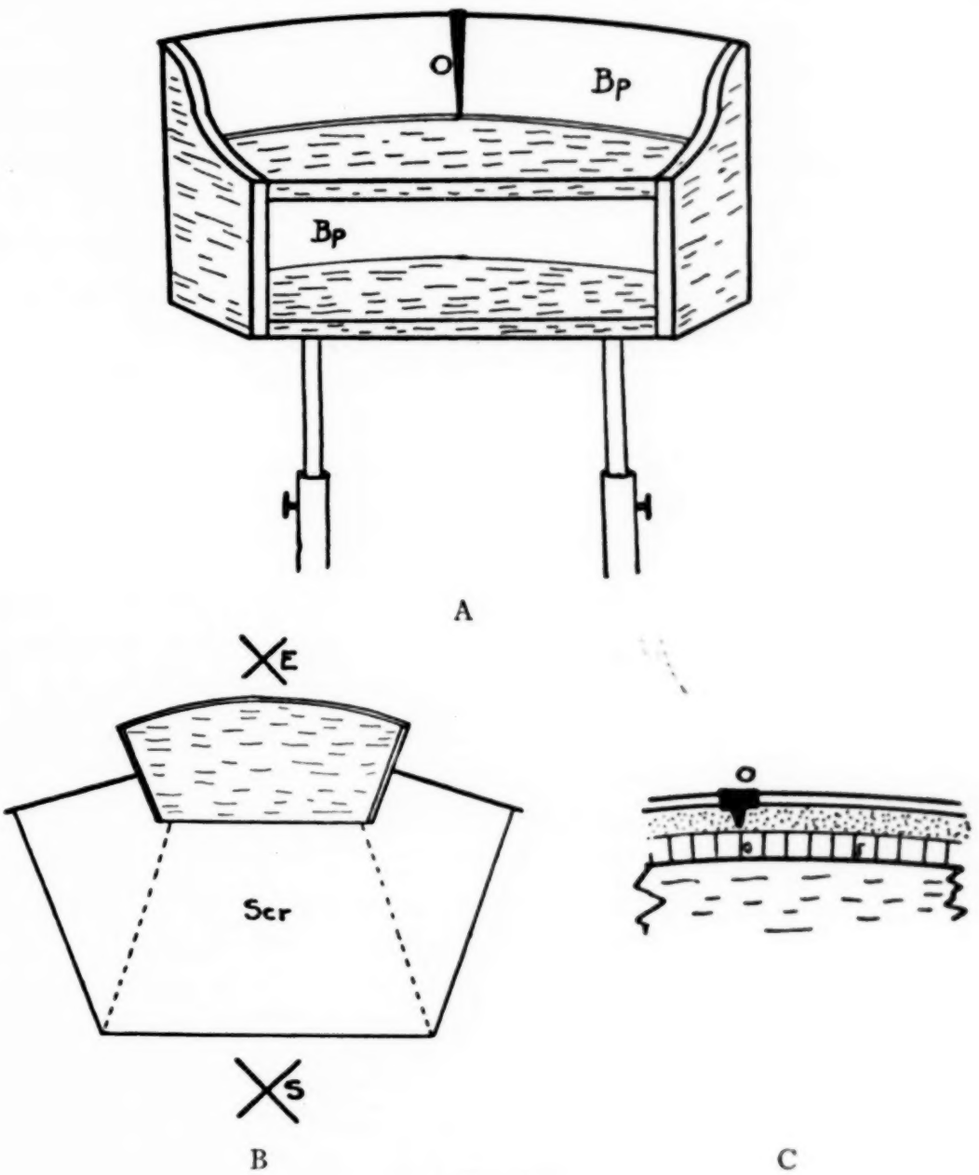

FIG. I

in a brass frame. Through a snugly fitting slide in this frame were two small apertures, one before each eye. These apertures were a half inch in length and an eighth in width, and admitted the only light entering the subject's eyes. The vis-

ual field through the eye piece was thus considerably limited. Under various horizontal adjustments of the slide the relation of the axis of the head to that of the eyes could be changed from coincidence to divergence to the right or to the left. The eye piece was secured to the head by an elastic band, and felt padding about the eyes assured a comfortable and yet snug fit.

A pointed finger-cap of brass and wood which fit over the index finger of the reacting arm made the point indicated more readily distinguished by the experimenter. It also prevented the subject from obtaining tactual cues as to the position of localization.

All of the ten subjects were graduate students in the University of Chicago, eight of them in the Psychology department. Six subjects (*McB*, *WB*, *T*, *S*, *H*, *K*)served in the first experiment, while *WB* and the remaining four (*Sa*, *G*, *A*, and *W*) took part in Experiment II. It was not essential that the same subjects sit for both series since each was in itself a distinct experiment.

Experiment I

The immediate problem of the first series might be stated as follows: What is the effect upon the direction of response, in localizing a fixated visual object, of varying the relation of the plane of the head to the planes of the eyes and of the body from the normal condition in which the three coincide? To obtain experimental data to answer this question it was necessary to control the position of the head so that it could be varied independently of the eyes and the body. This was accomplished by the use of the afore-mentioned eye piece.

At the time of the initial sitting the subject was given a typewritten copy of instructions which briefly explained the method of procedure. No indication of the problem involved or of the purpose of the study was given. The procedure as indicated by the instructions is here more fully described.

The individual was seated at the position before the apparatus corresponding to *S* on Fig. I. B. Since this position was kept constant by having the chair set in holders fastened to the floor, variations in the distance and direction of the subject's head from the object were reduced to a minimum. The eye

piece was put in place, care being taken that it set squarely on the front of the head. The screen was then lowered about the individuals shoulders, and the height was properly adjusted to give maximum ease in the localizing movement as well as to insure clear and direct vision of the object.

The experimenter took his position and directed the subject to fixate the object carefully. In fixating he was to turn the body and head in any way necessary to keep the object in the center of the restricted field of vision and in the position of clearest vision. The subject was then instructed to reach out with his capped index finger and to indicate the point on the backplate corresponding to the position of each object as seen. The direction and amount of error of each response were noted and a verbal signal given for the subject to withdraw his arm. Positions of localization were recorded in units of the scale to which we have referred, the symbols *R* and *L* indicating the direction of the error from the real position of the object. At no time was the subject given an indication of his accuracy or of his errors.

Localizations were made under three conditions as determined by the adjustment of the eye piece worn. Under the standard or control condition head and eye axes coincided as in normal vision; when the eyes fixated the metal strip, the median plane of the head, extended, also fell upon the object. This was accomplished by setting the apertures at the proper positions before the tubes of the eye piece (at *o–o*). When the apertures were set at 5 points to the right or to the left of that standard position, the plane of the head diverged from the plane of the eyes approximately 12 degrees to the left or to the right, respectively, when fixation was upon the object. At the distance of the backplate the divergence equalled 30 scale units or about 15 centimeters.

The object to be located was placed at one of three positions on the backplate—at *o* or the center, and at 40 scale units to the right and to the left of *o*. The object was localized under each of the three head conditions for each of its three positions on the back. An equal number of readings was taken for all combinations of head conditions and posi-

tions of the object, and the order of the combinations was varied in each sitting. The first two sittings of each subject were regarded as a practice period, and the records were not included in the tabular results.

Forty localizations were made during each sitting, and ten seconds were allowed for each localization, a period sufficiently long for the subject to withdraw his arm to his side, relax, and then prepare for another response upon receiving the proper signal. As a rule two sittings were given each day with a constant interval of not less than an hour between them. The influence of fatigue was avoided as far as possible.

The results of the six subjects are presented in Table I. In

TABLE I

SHOWING EXTENT AND DIRECTION OF ERROR OF LOCALIZATIONS UNDER THREE CONDITIONS FOR EACH POSITION OF THE OBJECT

Pos. of Object		20 cm Left			0			20 cm Right		
Head Axis to Eye Axis		*HL* 30	*HN* 0	*HR* 30	*HL* 30	*HN* 0	*HR* 30	*HL* 30	*HN* 0	*HR* 30
McB	Av. Error	1.17 *L*	.17 *R*	2.25 *R*	4. *L*	2.3 *L*	.14 *L*	3.14 *L*	1.25 *L*	.8 *R*
	P. E.	±.36	±.36	±.28	±.3	±.34	±.24	±.27	±.2	±.26
WB	Av. Error	9.08 *R*	11.7 *R*	11.8 *R*	8.5 *R*	9.8 *R*	10.9 *R*	7.8 *R*	10.7 *R*	11.8 *R*
	P. E.	±.23	±.26	±.23	±.19	±.25	±.2	±.22	±.26	±.24
H	Av. Error	2.6 *L*	.08 *R*	.63 *R*	2.4 *L*	.52 *R*	.81 *R*	2. *L*	1.14 *R*	.28 *R*
	P. E.	±.28	±.25	±.28	±.25	±.3	±.26	±.22	±.28	±.28
S	Av. Error	3.6 *L*	1.8 *L*	.47 *L*	1.9 *L*	1.2 *L*	.55 *L*	.9 *R*	1.1 *R*	1.7 *R*
	P. E.	±.2	±.18	±.19	±.21	±.18	±.2	±.25	±.19	±.23
T	Av. Error	3.5 *R*	3.2 *R*	5.8 *R*	5. *R*	3.4 *R*	6.1 *R*	5.2 *R*	5. *R*	7.2 *R*
	P. E.	±.36	±.24	±.28	±.33	±.27	±.24	±.3	±.28	±.28
K	Av. Error	3.5 *L*	2.7 *L*	1. *L*	2.9 *L*	1.7 *L*	1.5 *L*	2. *R*	3. *R*	4. *R*
	P. E.	±.34	±.29	±.33	±.34	±.27	±.34	±.28	±.22	±.3

the second horizontal column are indicated the positions of the median plane of the head relative to the fixation point of the eyes. Thus *HN* 0 refers to the normal condition under which head and eye axes coincide. It is with the results of this control condition that we compare the data obtained when the median plane of the head is shifted to one side or the other. *HL* 30 indicates that the axis of the head is 30 points (as determined on the scale) to the left of the fixation point of the eyes, viz., the position of the object. The symbol *HR* 30 has a similar significance but refers to the right. All of these conditions are found for each of the three positions of the metal strip on the backplate; at *o*, and at 20 centimeters to the left and to the right. The letters *L* and *R* accompanying the records for each subject designate the direction of that error from the real object.

Since individual differences in the direction of the errors were marked it was considered advisable to treat independently the results of each subject. A combination of the records would have resulted in a magnification of the standard deviation and the probable error (P.E.) and since significance of the data was determined on the basis of the latter the records of each subject were kept distinct.

Results

1. *Constant Error of Localization.*—The data in Table I reveal the presence of a constant error of localization whose direction and extent varies with the individual and with the position of the metal strip on the backplate.

The direction and size of these errors under the normal condition are to be found in the columns headed by the symbol *HN* in the table. These records are listed separately in Table II. It will be noted that *WB*, *H*, and *T* localized to the right of the object for all three positions. *WB* exhibited the greatest error and *H* the minimum. The other subjects localized to the left for two positions, and to the right for one position of the object.

2. *Influence of Head Position in Relation to the Eye Axes.*—A deviation of the head position from the normal con-

TABLE II

SHOWING CONSTANT ERROR OF LOCALIZATION FOR THREE POSITIONS OF THE OBJECT WHEN PLANES OF HEAD AND EYES COINCIDE

Head Axis to Eye Axis		HN 0			Head Axis to Eye Axis		HN 0		
Pos. of Object		20 cm *L*	0	20 cm *R*	Pos. of Object		20 cm *L*	0	20 cm *R*
McB	Av. Error	.17 *R*	2.3 *L*	1.25 *L*	*S*	Av. Error	1.8 *L*	1.2 *L*	1.1 *R*
	P. E.	±.36	±.34	±.2		P. E.	±.18	±.18	±.19
WB	Av. Error	11.7 *R*	9.8 *R*	10.7 *R*	*T*	Av. Error	3.2 *R*	3.4 *R*	5. *R*
	P. E.	±.26	±.25	±.26		P. E.	±.24	±.27	±.28
H	Av. Error	.08 *R*	.52 *R*	1.14 *R*	*K*	Av. Error	2.7 *L*	1.7 *L*	3. *R*
	P. E.	±.25	±.3	±.28		P. E.	±.29	±.27	±.22

dition of a coincidence of the planes of the head and the eyes also influenced the extent and direction of the error of localization. When the median plane of the head was held to the left of the axes of the eyes by means of the eye piece, the error was consistently well to the left; when the head axis was held to the right of the fixation point of the eyes, the error was regularly to the right of the normal localization.[5] The degree of this influence can be ascertained by computing the direction and distance of the localizations for the two head positions, *HL* 30 and *HR* 30, from the point localized under the normal condition, *HN* 0. Thus, subject *McB*'s localization for *HL* 30 (Table I) is at 1.34 scale units to the left of the localization for *HN* 0; the point of localization for *HR* 30 is 2.08 scale units

[5] The deviation of *HR* 30 deflected the localizations to the right with but one exception in the 18 cases: the localization of *H* when the object was at the position 20 cm right.

The opposite deviation of *HL* 30 deflected the localizations to the left for five of the six subjects; subject *T* was the exception.

In all cases, the localizations under condition *HR* were to the right of the point of localization when the median plane of the head was to the left of the fixation point.

to the right of that for *HN* o. The data computed in this manner from Table I appear in Table III.

TABLE III

SHOWING DIFFERENCES OF ERROR FOR THE COMPARED CONDITIONS

Pos. of Object		20 cm Left		o		20 cm Right	
Conditions Compared		*HL* 30 / *HN* o	*HR* 30 / *HN* o	*HL* 30 / *HN* o	*HR* 30 / *HN* o	*HL* 30 / *HN* o	*HR* 30 / *HN* o
McB	Diff.	1.34 *L*	2.08 *R*	1.7 *L*	2.16 *R*	1.89 *L*	2.05 *R*
	P. E. of Diff.	±.5	±.45	±.45	±.42	±.34	±.33
WB	Diff.	2.62 *L*	.1 *R*	1.3 *L*	1.1 *R*	2.9 *L*	1.1 *R*
	P. E. of Diff.	±.38	±.38	±.31	±.32	±.34	±.35
H	Diff.	2.68 *L*	.55 *R*	2.92 *L*	.29 *R*	3.14 *L*	.86 *L*•
	P. E. of Diff.	±.38	±.38	±.39	±.4	±.36	±.4
S	Diff.	1.8 *L*	1.33 *R*	.7 *L*	.65 *R*	.2 *L*	.6 *R*
	P. E. of Diff.	±.27	±.26	±.28	±.27	±.31	±.3
T	Diff.	.3 *R*•	2.6 *R*	1.6 *R*•	2.7 *R*	.2 *R*•	2.2 *R*
	P. E. of Diff.	±.43	±.37	±.43	±.36	±.41	±.39
K	Diff.	.8 *L*	1.7 *R*	1.2 *L*	.2 *R*	1. *L*	1. *R*
	P. E. of Diff.	±.45	±.44	±.43	±.43	±.36	±.37

The size of the deflection of the response was much less than the extent of the head deviation. Although the deviation of the plane of the head from the axes of the eyes amounted to about 15 centimeters at the distance of the backplate, the mean difference in the error of localization which accompanied the change in head position was from one-half to one and one-half centimeters, less than 10 percent of the former.

Discussion

In an earlier investigation, the conditions of which were similar to those of our experiment, Professor Carr noted the phenomenon of the constant error of localization. He used the same apparatus with the exception of the eye piece; the field of vision of his subjects was not restricted. The existence of the phenomenon is thus not dependent upon the use of that part of the apparatus.

The results obtained by Professor Carr have not been published. His results confirm our data which indicate that the size and the direction of the error vary with the individual and the position of the object. He found that with four subjects the size of the error varied with the hand used in making the localization; for one, the direction of the error was a function of the hand used. Responses were made with binocular vision and with each eye used separately. Varied conditions of vision did not affect the error of localization with some subjects. Monocular vision seemed to increase slightly the size of the error with some individuals, and it changed the direction of the error for the right hand localizations of one subject. With one individual the direction of the error was a function of the particular eye-hand coördination employed. Upon retesting one subject after an interval of a year and a half, Professor Carr found that the direction and approximate size of the individual's constant error had remained unchanged.

The records of all of the subjects in our experiment reveal a marked constant error. This deviation varies from approximately one and one-half centimeters to the left to over five centimeters to the right. What factors underlie this marked and consistent error under normal vision?

It was first suggested that the eyedness of the subject might determine the accuracy of his localizing response, more particularly, the direction of his error in making such a response. Consequently each individual taking part in the experiment was tested by the objective method for determining ocular dominance described by Miles.[6] The test was repeated a number of times with each individual and results the

[6] Miles, W. R., this Journal, April 1929.

were strikingly conclusive: all of the subjects tested were right-eyed. Since only three showed consistent errors to the right in the original experiment, and since the individual differences in the extent of the errors was great, eyedness was not held to be a decisive factor determining the constant error.

A report concerning certain optical peculiarities of one of the subjects suggested a possible explanation of his constant error. The records of *WB* reveal the most striking error, one of at least 5 centimeters to the right of the real position of the object. *WB*'s eyesight is defective, but the use of proper lenses in his glasses corrects this abnormality. But the construction of our eye piece did not permit the wearing of glasses during the sittings. It is reasonable to assume that the eye-hand coördination of *WB* is built up about his vision with glasses. We further assume that due to the refraction of light by the glasses the eye-hand coördination has developed in such a way that in responding to the visual object *WB* consistently reached to the right of its apparent position and made the correct localization. The situation is similar to that recorded in Stratton's account of his experiment with distorted vision.[7] With the glasses removed as in the experiment the regular habit system functioned and *WB* constantly localized to the right of the actual position of the object. It was readily possible to test this hypothesis and a short experiment was introduced for that purpose.

Additional apparatus for this series consisted of a felt mask which fit snugly about the face of the subject and yet permitted him to wear his glasses. Apertures the exact size of those in the eye piece and the same distance apart were cut in the mask. When the apertures were in their proper positions before the eyes the conditions were similar to those of the control series of Experiment I, except that the lenses of glasses had been introduced.

Two conditions of response were involved in this experiment and the results were compared with the records of the control series of the original experiment. Under condition 1 the felt mask replaced the eye piece and the subject wore his

[7] STRATTON, G. M., *Psychol. Rev.*, Vol. 4, p. 431 and p. 463.

usual glasses. For condition 2 the felt mask was again used but localizations were made with the left hand rather than with the right. The average error and its direction under the three conditions are given in the following table.

TABLE IV

Pos. of Object	Eye Piece Right Hand			Glasses Right Hand			Glasses Left Hand		
	20 cm *L*	0	20 cm *R*	20 cm *L*	0	20 cm *R*	20 cm *L*	0	20 cm *R*
Av. Error....	*R* 11.7	*R* 9.8	*R* 10.7	*R* 5.5	*R* 5.3	*R* 8.5	*L* 5.2	*L* 4.4	*L* 7.1

It can readily be seen that *WB*'s error was appreciably reduced when he was permitted to wear his glasses at the sittings. The error which remained was practically offset by the deviation in the opposite direction when the left hand made the localizing response. In the case of *WB*, then, the error of response was primarily due to the subject's specific eye-hand coördination developed about his optical peculiarities. Professor Carr's results, to which we have already referred, suggest that the constant error of at least one of his subjects was based upon similar ocular conditions with the accompanying coördinations. The constant errors of our other subjects were less marked than the error of *WB*; further study might indicate that they were due to similar causes.

It is probable that no one explanation of the constant error is sufficient for all of the cases. Several factors may contribute to determine the error, as in the case of *WB*, but probably one predominates in each instance.

An explanation of the deflection of the response accompanying the change of head position has been suggested in our introductory paragraphs. Under normal conditions the object to which one reacts with a localizing arm movement is situated approximately directly in front of the head. Our coördinations are built up on that basis, and the habit persists when the changed laboratory conditions prevail. The subject's reactions are still influenced by head position and we notice the type of response given in our experiment. Such a habit

apparently predominates in the majority of cases, and determines the response.

Apparently other factors operated to minimize the effect of head position, since, as we have noted (Table I) the extent of the deflection of the error when the eyes and plane of the head did not coincide was only 10 percent of the deviation of the head axis from the fixation point of the eyes. Position of the torso may have contributed to offset the effect of the head position; body position was not controlled in our experiment, however, and we have no quantitative measure of its effect. If it had a significant effect upon the localization, one should expect to find that the deflection of the position of localization was consistently greater under the conditions in which both the median plane of the head and the dorso-ventral axis of the body were to the right or to the left of the fixation point of the eyes. Assuming that the axis of the body did not change more than ten degrees under the various conditions of the experiment, both the head axis and the axis of the body were to the right of the fixation point when the condition *HR* 30 with the object at 20 cm left prevailed. Similarly, both axes were to the left of the axis of the eyes under the conditions *HL* 30 and with the metal strip at 20 cm right on the backplate. But in studying Table III we note that the deflection of the position of localization is greater in less than 50 percent of the cases when the factors of head and body position combine than when they are antagonistic. This would indicate that the effect of the position of the body during the localization is negligible.

It is in the results of subjects *T* and *H* that we find the four outstanding exceptions to the observed correspondence of head position to the direction of the localizing response. Three of these are from *T*, while *H* presents the fourth. These negative records are indicated by asterisks in Table III.

Although holding the head to the right of the eye axis had a significant positive effect upon the responses of *T*, the data show that holding that subject's head to the left of the fixation point gave negative results, in view of those obtained from the other subjects. The one case of subject *H* is similar. For these exceptions we have no additional data which might suggest explanations.

Experiment II

The purpose of our second experiment was to determine the possible change in the localizing response which might accompany changes in the relation of the object to the restricted visual field.

The apparatus of the preceding experiment was used and the procedure was similar to that previously described. Localizations were made with the object at the three standard positions, at *0*, at 20 centimeters to the right and to the left. The subject was asked to adjust so that the metal strip was seen at one of three specified positions in the restricted visual field, viz., at the center, the right edge, or the left edge. By means of the horizontal slide in the eye piece, the experimenter adjusted the relation of the apertures in the slide to the sub-

TABLE V

The Amount and Direction of the Average Error of Localization with Object at Three Positions in the Visual Field

Pos. of Object		20 cm Left			0			20 cm Right		
Object in Vis. Field		*LE*	*C*	*RE*	*LE*	*C*	*RE*	*LE*	*C*	*RE*
WB	Av. Error	3.8 *R*	5.6 *R*	9.5 *R*	4.5 *R*	6.4 *R*	10.6 *R*	7.6 *R*	9.9 *R*	11.4 *R*
	P. E.	±.24	±.22	±.29	±.31	±.24	±.28	±.24	±.27	±.25
G	Av. Error	4.6 *L*	3.3 *L*	.43 *L*	6.2 *L*	4.45 *L*	3. *L*	5.15 *L*	3.2 *L*	1.8 *L*
	P. E.	±.2	±.22	±.22	±.2	±.22	±.23	±.23	±.22	±.22
A	Av. Error	.9 *L*	.6 *L*	1.9 *R*	2.4 *L*	1.6 *L*	.7 *R*	.2 *L*	.5 *R*	1.9 *R*
	P. E.	±.31	±.36	±.35	±.42	±.36	±.29	±.29	±.24	±.29
W	Av. Error	3.5 *L*	1.6 *L*	1.3 *L*	2. *L*	.47 *L*	.47 *R*	2.5 *R*	3.5 *R*	5.1 *R*
	P. E.	±.2	±.18	±.2	±.22	±.2	±.21	±.24	±.21	±.2
Sa	Av. Error	.21 *R*	1.4 *R*	3.3 *R*	2.6 *L*	.32 *L*	.12 *R*	4.9 *L*	2.4 *L*	1.6 *L*
	P. E.	±.26	±.25	±.25	±.27	±.24	±.25	±.22	±.23	±.24

ject's head so that the median plane of the head in reference to the plane of the eyes was held constant regardless of the varying positions of the fixated object in relation to the restricted field of vision. This constant relation of the plane of the head to that of the eyes was one of approximate coincidence. The localizations were thus made under the following conditions: the object was located at each of three positions on the backplate; the object was fixated in the center, at the right edge, and at the left edge of the limited visual field; the relation of the median plane of the head to the eyes was held constant and in the normal condition of approximate coincidence. The order in which these variable positions were presented was varied in a systematic manner.

Table V presents the data of the responses for this experiment. In the second horizontal column are listed the conditions, the positions of the object as seen in the restricted visual field. The symbol *LE* indicates that the object was on the left edge, *C* that it was in the center, and *RE* that it was on the right edge of the visual field. All of these are given for each of the three positions of the metal strip (column one).

Results

1. *Constant Error of Localization.*—The constant error of localization under normal conditions is indicated by the data in the vertical columns headed *C*. As in Experiment I, the size and the direction of the constant error varies with the individual and with the position of the object on the backplate. The direction of the error of *WB* is to the right, the same as in the previous experiment. In extent, his error is appreciably less than in the earlier experiment.

2. *Influence of the Position of the Object in the Field of Vision.*—The data of Table V show a deflection from the normal localization when the object is seen on the left or the right edge of the visual field. The amount and direction of this deflection for each of the three positions of the object is given in Table VI.

When the eye piece was so adjusted that the metal strip

TABLE VI

SHOWING AMOUNT AND DIRECTION OF DEFLECTION OF RESPONSE ACCOMPANYING CHANGE OF POSITION OF OBJECT IN THE VISUAL FIELD

Pos. of Object		20 cm Left		0		20 cm Right	
Conditions Compared		$\frac{LE}{C}$	$\frac{RE}{C}$	$\frac{LE}{C}$	$\frac{RE}{C}$	$\frac{LE}{C}$	$\frac{RE}{C}$
WB	Diff.	1.8 *L*	3.9 *R*	1.9 *L*	4.2 *R*	2.3 *L*	1.5 *R*
	P. E. of Diff.	±.32	±.36	±.39	±.37	±.36	±.37
G	Diff.	1.3 *L*	2.87 *R*	1.75 *L*	1.45 *R*	1.95 *L*	1.4 *R*
	P. E. of Diff.	±.30	±.31	±.30	±.32	±.32	±.31
A	Diff.	.3 *L*	2.5 *R*	.8 *L*	2.3 *R*	.7 *L*	1.4 *R*
	P. E. of Diff.	±.48	±.5	±.55	±.46	±.38	±.38
W	Diff.	1.9 *L*	.3 *R*	1.53 *L*	.94 *R*	1. *L*	1.6 *R*
	P. E. of Diff.	±.27	±.27	±.3	±.29	±.32	±.29
Sa	Diff.	1.19 *L*	1.9 *R*	2.28 *L*	.44 *R*	2.5 *L*	.8 *R*
	P. E. of Diff.	±.36	±.35	±.36	±.35	±.32	±.33

which served as object was seen on the left edge of the field of vision, the accompanying response was invariably deflected to the left. When the object was seen at the right edge of the field, the localizing response was consistently to the right of the position of the normal response.

The size of the deflections to the left or right, although unequal, seems to bear no constant relation to the conditions. For none of the five subjects is the larger deflection regularly to the right or left for each of the positions of the object on the backplate.

Although the size of the deflections varied, the reactions of each subject under all conditions indicated that the position of the object in the restricted visual field was a factor of marked importance in determining the accuracy of a localizing

response made toward that object. There were no exceptions.

Discussion

No explanation which we can offer will account satisfactorily for the decrease in the size of *WB*'s constant error from the first experiment to the second. The procedure under the control condition of both series was the same, yet the deviation in the second was from 2 to 6 scale units less than his error in Experiment I.

Practice gained in making the localizations probably was of importance in reducing the constant error. Regularity as to the point of greatest improvement is lacking, however. For one position of the object (20 cm L) the most marked decrease in the error apparently occurs during the interval between the first and second experiments, when no localizations were made. For the two remaining positions of the object on the backplate, the most marked improvement comes in the course of the sittings of Experiment II. Although the subject was never informed as to the correctness of his responses, he may have gained some information concerning his error from chance observation of the data sheet, or through conversation with the experimenter during the intervals between sittings.

An explanation of the deflection noted in the accompanying tables must take into account the habitual system of reaction of the individual as it is developed in ordinary daily activity. Normally, when one fixates an object preparatory to reacting to it, the object lies in the center of the visual field. Objects not in the center lie to the right or to the left and require a response in one of these directions in our reactions toward them. Practically all of our various movements are carried out under such conditions, and our eye-hand coördinations are developed on that basis. These habits strengthened through daily use carry over into the controlled conditions of our experiment, and we obtain the results previously stated. The subject notes the object at the left or right edge of the field of vision rather than at the center, its normal position. He corrects for it, and as a result, he makes his localizing response to the left or to the right, respectively.

Such an explanation meets well all of the facts, and is consistently supported by the data of the accompanying tables.

Summary

1. The constant error of localization in our experiments varied with individuals, and also with the position of the object for any one individual.

The direction of this deviation and probably its size also depended upon the coördinations of the subject developed about his ocular peculiarities. The extent and direction of this constant error was also a function of the hand used in making the localizing movement.

2. Head position in its relation to eye axes was a significant factor determining the accuracy of the localizing response. There was for most subjects an appreciable deflection of the response to the right or to the left when the deviation of head axis from the fixation point of the eyes was to the right or to the left respectively. Whether there is a constant relation between the extent of the deviation and the size of the deflection is a question to be answered through later research.

This conclusion supports the hypothesis advanced by Miss Wooster and stated earlier in this account. The habitual system of response to head front might well have been the primary causal factor in the readjustment revealed by her subjects.

3. The direction and size of the error of localization was also dependent upon the position of the object in the visual field. A central position of the object seemed to make for the least error, while a peripheral position resulted in a deflection of the response in the direction corresponding to the position of the object in the field of vision.

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DOES THE HYPNOTIC TRANCE FAVOR THE RECALL OF FAINT MEMORIES?[1]

BY BETTY HUSE

The Problem

It has long been known that it is occasionally possible to recover lost memories in the hypnotic trance when no amount of voluntary effort will do so. It is agreed that many of the memories thus recovered have been associated with traumas of a somatic or emotional nature. In such cases hypnosis appears merely to perform the function of removing a traumatic inhibition to recall. But quite apart from this, there is a rather widespread impression among psychologists that somehow the hypnotic trance also lowers the threshold of recall for faint memories in general. It was to investigate this latter problem that the present investigation was undertaken.

Experimental Procedure

The procedure was based on the assumption that, after a period of forgetting such that a certain proportion of the learned excitatory tendencies have passed below the threshold of normal recall, an appreciable number of these will be just barely below the threshold, and that an appreciable number of those above the threshold will be just barely above. It follows that if the hypnotic trance really lowers the threshold of recall, those excitatory tendencies just barely subliminal to normal recall will become supraliminal, with a corresponding increase in the score of trance recall over that in the waking state. If, on the other hand, the score of recall in the trance should be found to be less than in the waking state, the indication would be that the threshold of recall in the trance is higher.

[1] From the Psychological Laboratory, University of Wisconsin. This is the eighth of a series of experimental studies concerning the psychology of hypnosis and suggestibility. The writer is indebted to Prof. Clark L. Hull for advice and assistance.

In order to determine the difference in memory between the trance and normal states, memorized material was recalled in trance and normal states and the difference in amount of spontaneous recall was computed. The memorial material employed was used and described by Clinton B. Strickler.[2] It consisted of nonsense symbols to which nonsense-syllable names had been assigned. A group of nine such paired associates, constituting one series, was arranged in eight different orders; each of these arrangements of nine symbols made up what will hereafter be referred to as one cycle.

All of the learning was done in the normal waking state. The *Ss* learned four series (one band) in one day, and came back on the next day at the same time for the retention tests; thus there was an interval of approximately twenty-four hours between the learning and the recall.[3]

In the retention tests, each series of characters was exposed through three cycles. The subject pronounced aloud the names of those symbols which he could recall. A perfect score for a given series was thus 27 correct reactions. After all four series had been thus tested, one after the other, in (say) the normal state, the subject was put into a trance and all four series were again run through three cycles each to test the recall in the trance.

Subjects.—Eight *Ss* were used in this experiment. All were students at the University of Wisconsin. Five were girls and three were men. The individual variations in status between the subjects were great as may be indicated by the fact that two were freshmen, two sophomores in the Letters and Science course, one a junior music student, one a first year law student, one a graduate student in psychology, and the eighth in his second year at the Experimental College. With two exceptions, the subjects showed consistently all the phenomena of deep trance, including catalepsy, analgesia, deafness,

[2] C. B. Strickler, A quantitative study of post hypnotic amnesia, *J. Abn. & Soc. Psychol.*, 1929, 24, 108–119.

[3] In the case of one *S*, unexpected circumstances caused two postponements of the recall tests to forty-eight instead of twenty-four hours; but since one favored the normal and the other the trance recall, the two postponements were judged approximately to equalize one another.

amnesia, and post hypnotic suggestion. Subjects *W. S.* and *D. B.* did not always have complete amnesias.

The eight subjects were divided into four squads of two each. The first squad recalled the first band (four series) in the normal state first, the second and third bands (eight series) in the trance state first, and the fourth (four series) in the normal state first. The second squad used the same *ABBA* order, recalling the first band in the trance state first, the second and third bands in the normal state first, and the fourth band in the trance first. The third and fourth squads recalled in the same order as the first and second respectively, but the order of bands learned was reversed. By running the squads in this way, the experiment was designed to correct for practice effects, difficulty of series, and variability of subjects. A chart is shown below which indicates exactly how the experiment was run.

In several cases the last series in the experimental run was exposed through eight or more cycles in order to see whether many more symbols would be recalled with more extended opportunity. In one case, one more symbol was recalled on the eighth cycle; in another case, one more symbol was recalled in the seventh cycle, but was subsequently forgotten again. It seems, therefore that three cycles of exposure was enough to test almost all of the recall.

A. *Learning.*—The subject was seated in front of the memory machine and shown a symbol exposed at the window. The following instructions were then given:

"As each symbol appears for the first time at the window, I shall tell you its name. Afterwards when you see it again, if you remember the name you are to pronounce it out loud. In case you do not remember the name, I will tell you its name again; or if you make a mistake, I shall correct you. We shall continue until you have pronounced each name correctly through two successive cycles."

The learning was then carried on according to instructions. Mimeographed sheets were used for prompting and recording; when a symbol was rightly named, a check was made in the square opposite it; otherwise, no mark was made.

B. *Normal Recall.*—The subject was again seated before

the memory machine and the following instructions were given:

"I am going to show you the symbols you learned yesterday. If you see a symbol whose name you remember, you are to pronounce it aloud. I shall not prompt you this time."

Mimeographed sheets were again used for recording. When a symbol was correctly named, a check was made in the square opposite; when a symbol was incorrectly named, the incorrect name was written in the square; when no response was made, no mark was recorded.

TABLE I

LEARNING AND TESTING SCHEDULES OF THE SEVERAL GROUPS OF SUBJECTS

N = normal state; *T* = trance state.
N-T = tested first in normal, then in trance state.
T-N = tested in reverse order.

Experiment Day	Activity	Subjects. Group 1	Subjects. Group 2	Subjects. Group 3	Subjects. Group 4
Day 1.....	Learn	Practise Series	Practise series	Practise series	Practise series
Day 2.....	Recall	Practise series *N–T*	Practise series *N–T*	Practise series *N–T*	Practise series *N–T*
	Learn	Band A	Band A	Band D	Band D
Day 3.....	Recall	Band A *N–T*	Band A *T–N*	Band D *N–T*	Band D *T–N*
	Learn	Band B	Band B	Band C	Band C
Day 4.....	Recall	Band B *T–N*	Band B *N–T*	Band C *T–N*	Band C *N–T*
	Learn	Band C	Band C	Band B	Band B
Day 5.....	Recall	Band C *T–N*	Band C *N–T*	Band B *T–N*	Band B *N–T*
	Learn	Band D	Band D	Band A	Band A
Day 6.....	Recall	Band D *N–T*	Band D *T–N*	Band A *N–T*	Band A *T–N*

C. *Trance Recall.*—The subject was seated as comfortably as possible before the memory machine. All of the subjects had been previously trained to go into deep trance; and the

hypnotic technique which had been used in training was continued in this experiment. This technique varied but little; the eyes of the subject were fixed on a bright object or on the experimenter's eyes, and suggestions of relaxation and sleep were made. Except in a few cases in which the subjects had been exceptionally well-trained and fell immediately into a deep trance, catalepsy of the arm and then complete relaxation of it were usually induced. The subject was generally asked to raise his hand and touch the experimenter's hand when he felt himself to be in a deep trance.

When a deep trance had been induced, the experimenter withdrew to a high stool behind the memory machine, telling the subject to go on sleeping. Then the following instructions were given:

"When I give the signal, your eyes are going to open, but you are going to stay sound asleep. Do you understand? "

Here the experimenter waited for affirmation and then continued,

"You are going to look at the window, and the symbols which you learned yesterday will be exposed one by one. If you see a symbol and remember its name, you will pronounce it out loud and distinctly so that I can understand it. I will not prompt you this time. Do you understand? "

After each question the experimenter awaited affirmation.

"Your eyes will open and you will stay sound asleep. You will go even deeper asleep when your eyes are open, won't you? Your eyes will stay open until I tell you to close them. All right, now you are sitting up straight in your chair. Now your eyes are opening and you are staying sound asleep. Sound asleep."

In some cases, it was necessary to reinforce the suggestion that the eyes would remain open, or the subject was asked to speak more distinctly; otherwise, the experimenter said nothing more until the three cycles had been run through. The subject was then told to close his eyes and go on sleeping. He was given a small interval of rest, and was then told to open his eyes again, in the same way as described above, except that the directions for recall were abbreviated. The experimenter usually said, "You are going to recall this series in the same way that you recalled the last. You remember, don't you?"

The recording was done in the same way as that described above for normal recall. After four series had been recalled, the subject was allowed to sleep quietly for two or three minutes. The following instructions were then given:

"When you wake up you will not remember a thing that has happened during the trance. You will not remember anything at all that has happened in the trance. Do you understand? You won't remember anything about it, will you? "

The subject was then given the usual suggestions that he would feel refreshed and rested and wide-awake when he awoke, and he was then wakened by the pre-arranged signal of snapping the fingers.

Usually on the first and last days of the experiment, the subject was given a post-hypnotic suggestion to perform immediately upon waking or at a given signal. For example, one subject was told to move her hat from one table to another; several were told to ask for cigarettes; and other suggestions of a like nature were given. This was done as an additional check on the depth of the trance.

Results

It will be remembered that each subject was tested twice for recall on each set of material learned, first in the normal state and then in the trance state or vice versa. As the experiment was originally set up, the data were to be computed by adding together all of the correct recall responses made in the normal state, and all of those made in the trance state, regardless of which was tested first. It was believed at first that the use of the *ABBA* order (see Table I) would so control the experiment that any advantage for trance recall on one occasion would be balanced by an equal advantage for the normal recall on another. Accordingly, the data were first figured out in this way.

The data are shown in Table II. Four totals are to be compared in trance and normal states. The first three, listed under Cycles 1, 2, and 3, are the recall-responses made to the three successive exposures of the learned material. It was found that sometimes a symbol recalled in, say, the first cycle, would be forgotten in the second and third; or that some sym-

TABLE II

SUMMARY OF EXPERIMENTAL RESULTS BY FIRST METHOD OF COMPUTATION

Subj.	Original Learning		Recall							
			Normal				Trance			
	No. of Cycles	No. of Prompts	Total No Successful Recalls per Cycle per Subject			Largest Total No. Successful Recalls	Total No. Successful Recalls per Cycle per Subject			Largest Total No. Successful Recalls
			1	2	3		1	2	3	
W. S.	115	408	37	40	40	44	43	50	50	52
M. B.	155	551	90	96	92	100	86	94	97	100
D. C.	182	576	33	36	39	39	34	39	40	42
K. J.	208	610	78	82	78	82	74	82	83	84
S. L.	151	459	33	36	38	38	32	33	33	35
D. B.	146	464	29	33	32	35	28	34	33	37
M. G.	118	401	45	45	41	50	41	44	44	46
I. Y.	146	420	19	23	24	25	21	25	23	25
Sums	1221	3889	364	391	384	413	359	401	403	421
Means	152.63	486.13	45.50	48.88	48.00	51.63	44.88	50.13	50.38	52.63
P. E.$_M$	6.85	18.18	5.58	5.75	5.29	5.75	5.10	5.51	5.80	5.77

bols would not be recalled until the last cycle. Thus, a subject might recall all nine symbols during the course of the three exposures, though he recalled at most eight symbols in each cycle. Since the extent of recall is probably more important to this investigation than the quality of the recall, a fourth criterion was established: the number of symbols out of a possible nine recalled during the three exposures. The totals found on this basis for each subject are listed in the column headed *Largest total number.*

When the totals were computed in this way, it was found that in the first cycle there were 359 correct recalls in the trance, compared to 364 in the normal; in the second cycle, 401 in the trance, and 391 in the normal; and in the third cycle, 403 in the trance and 384 in the normal. The largest total number of correct responses in the trance was 421; in the normal, 413. That is, considering the last criterion, there was a gain in the trance of 1 recall per subject for all sixteen series. The probable error of that difference was computed to be .836. Thus, although the reliability of the result is very small, there

seemed to be some slight foundation for the belief that faint memory traces mediate recall better in the trance than in the waking state. This belief might be somewhat strengthened by the fact that of the eight subjects four showed superior recall in the trance, two in the normal, and two were equal in both. The table of total results for each subject is shown in Table II.[4]

When the experiment was critically scanned, however, it appeared that there was opportunity in this method of computation for a constant error to enter and obscure the results. According to what we know of hypnosis, there is in the trance no amnesia for what has occurred in the waking state; whereas in the waking state there is at least partial amnesia in the case of deep-trance subjects for what had happened in the trance. Strickler carried out an experiment on this point and found that, as tested by the re-learning method, there is with good hypnotic subjects about 98 percent recall-amnesia for nonsense-material learned in the trance. Thus, when the subject recalls the symbols in the waking state first, one would expect him to remember the result in the trance; but when he recalls them first in the trance he would not remember more than 2 percent of his responses when the symbols are again exposed in the waking state. This would tend to give a constant advantage to the trance recalls where they followed a waking recall.

This view is substantiated by the fact that in the experiment 10 symbols which were recalled in the first 3-cycle exposure were forgotten in the subsequent recall in the opposite state; and of those 10, 3 which were recalled in the waking were forgotten in the subsequent trance recall, whereas 7 which were first recalled in the trance were forgotten in the subsequent normal recall. This cannot of course serve as proof, since the number of cases is too few, but it does indicate the probability of the contention. It is likely that a good many such cases could be found.

In order to eliminate the possibility of this constant error, another means of computation was sought. Only the first

[4] The detailed data for individual subjects is given in the writer's A comparative study of recall in trance and normal states, Library of the University of Wisconsin, 1929 thesis.

recall of three cycles in trance or normal state as the case might be, was taken into consideration, and the second recall of the same series in the normal or trance state respectively was discarded. It will be observed from Table I that each set of memory material was used an equal number of times in the two states by this method, as well as by the first, so that no constant error could enter from inequalities in the material.

When the data were tabulated in this way, it was found that the largest total number of symbols correctly recalled by all the subjects in all the series was 204 in the normal, and 196 in the trance. (See Table III). This seems to show a mean

TABLE III

SUMMARY OF EXPERIMENTAL RESULTS BY REVISED METHOD OF COMPUTATION

Subject	Normal Recall				Trance Recall			
	Total No. Successful Recalls per Cycle per Subject			Largest Total No. Successful Recalls	Total No. Successful Recalls per Cycle per Subject			Largest Total No. Successful Recalls
	1	2	3		1	2	3	
W. S...	18	18	18	21	18	22	21	23
M. B...	42	46	46	49	40	47	47	50
K. J...	33	37	36	37	34	41	41	42
D. C...	15	16	17	17	16	18	18	20
S. L...	17	19	19	17	16	15	15	16
D. B...	12	17	16	18	13	17	16	19
M. G...	27	28	24	32	14	15	15	16
I. Y...	11	13	12	13	8	10	9	10
Sums...	175	194	188	204	159	185	182	196
Means	21.88	24.25	23.50	25.50	19.88	23.13	22.75	24.50
P. E.$_M$	2.45	2.60	2.57	2.79	2.46	2.98	3.03	3.10

gain of 1.00 per subject in the normal over the trance state. The probable error of the difference was found to be 1.48.[5] Of the eight subjects, 5 showed a gain in recall in trance over the normal, 3 showed superior recall in the normal state. Thus, there seems to be some advantage for the normal recall, but it is rather slight, and the statistical reliability is very low.

[5] It should be explained that the formula used for computing the probable errors of all the differences between means in this study involved the correlation between the two columns of data in question.

Totals for each cycle were computed according to the revised method, and the following results were obtained: in the first cycle, 175 correct responses were made in the normal, 159 in the trance; in the second cycle, 194 correct responses were made in the normal, 185 in the trance; in the third cycle, 188 in the normal, 182 in the trance. The mean advantage in the first cycle of normal over trance is 2.0 per subject, with a probable error of 1.04. The ratio of difference to probable error is 1.92. The mean advantage in the second cycle of normal over trance is 1.12 with a probable error of 1.24. The mean advantage in the third cycle of normal over trance is .75 per subject, with a probable error of .99. The ratio of difference to probable error is .76. This seems to indicate that the greateat advantage for normal over trance occurs in the first cycle; during the first cycle of exposure, it had been noticed by the writer that the trance subjects were often extremely drowsy and could only with difficulty hold their eyes open, and this fact probably accounts for the large advantage of the normal at this time. The second cycle also shows a gain in the waking state, but the probable error of the difference is larger than the difference. The third cycle in which the advantage of normal over trance is still less, also shows very poor reliability. These results are shown in systematic form in Table IV.

TABLE IV

SHOWING THE RELATIVE NUMBER OF CORRECT RESPONSES ON THE SEVERAL TEST CYCLES IN THE TRANCE AND WAKING STATES

	First Cycle	Second Cycle	Third Cycle
No. of correct responses in normal state	175	199	188
No. of correct responses in trance state	159	205	182
Mean gain per subject of normal over trance	2.0	1.12	.75
Probable error of difference	1.04	1.24	.99
Critical ratio $\left(\frac{D}{P.E._D}\right)$	1.92	.90	.76

From these results, then, the writer would conclude that there is no basis for the popular belief that faint memory traces mediate recall better in the trance than in the normal

state. The data seem to show, in fact, a slight advantage in favor of the normal; but since the ratios of difference to probable error are small, the writer is inclined to believe that there is no significant difference between recall in the trance and the normal states. To be credited with scientific significance the difference between two means should be at least two and one-half or three times as large as its probable error.

Summary

The data reported in this experiment show slightly more recall in the normal state than in the trance; however, the critical ratio is very low. There is probably no significant difference between recall in the trance and normal states of nonsense-material 24 hours after learning.

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